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Fundamentals To Get Power Plant Efficiency

Common Sense

Careful Planning of Plant, Organization and Methods

Regular Routine Operations According to Fully Detailed, Recorded Standards

Systematic, Continuous Testing of Plant and Separate Apparatus for a Well Defined Purpose

Reliable Records of Performance and Expense of Materials, Machinery and Men

Analytic Study of Records and Comparison with Standards of Possibility

Enthusiastic Co-operation Between Chief and Force

Training and Study to Increase Effectiveness of Men

Reward for Excellence in Results Obtained

Efficiency In The Power Plant

MATERIALS, MACHINERY AND MEN ARE ESSENTIALS IN POWER MANUFACTURING

IN ALL ESSENTIAL RESPECTS, the power plant is a factory which turns stored energy of fuel or the moving energy of air or water into a form to do useful work. Power from wind is negligible at present, because of its unreliability, although with increase in the cost of fuel, storage of energy from wind may become an important feature of power plant practice in the coming years. Efficiency of a water plant rests almost wholly on the design and equipment, as the only features controllable in operation are the distribution of load on the different units, and the methods of lubrication.

Increase in the cost of fuel, which is sure to continue and likely to be more rapid in the future than in the past, makes the question of efficiency in the plant, using heat as a source of power, one of the greatest importance. The points to be watched in order to secure plant efficiency are the same whether steam or gas be used as a working fluid, and as the steam plant is the more complicated, attention will be given to that in the discussion of the present issue.

HINTS ON FUEL

10% ash in coal permits 60% efficiency for boiler and furnace.

30% ash in coal permits 38% efficiency for boiler and furnace.

40% ash in coal permits 0% efficiency for boiler and furnace.

Ash should be under 15% for good results.

Sulphur in coal causes corrosion of plates and slag in the furnace.

Small, fine coal calls for large air supply and reduces efficiency.

Anthracite coal is not affected by weathering.

Bituminous coal loses 1% by weather "slacking."

The elements involved in a manufacturing power plant are 3 in number—namely, materials, machinery and men. Each of the 3 must meet the essentials, fitness for the work, capacity for big performance, and use to the best advantage, if the greatest success is to be attained. As to materials used in the power manufacturing process, the principal ones are coal, water and lubricant, of which the main expense is for coal, which constitutes about 68 per cent of the cost of power. For this reason, the boiler room is the most important part of the plant, and will be given consideration accordingly. Other materials, such as packing, waste, etc., while of the greatest importance, are matters which must be decided upon by experiment and trial in each case, so that no general study can be made of their properties or of their fitness for different conditions.

At the outset, it is important to know what materials are most available in any given locality, and to adapt the plant to these. Burning Pennsylvania coal in Illinois is wasteful and a luxury, and using Pennsylvania oil in Texas is unbusinesslike; but if equipment has been installed which cannot use the fuel or lubricant most available in a given locality, it sometimes becomes necessary to get at any price material suited to a plant, at least until the plant can be altered to use materials which can be obtained nearby.

SOURCES OF ENERGY LOSS (Hays)

	Avoidable	Unavoidable
Normal moisture in coal	....	1.5%
Weathering	....	1.0%
Scattering of coal	....	1.0%
Unburned coal in ash	....	1.0%
Radiation	....	4.0%
Average scale	9.0%	....
Average soot	7.0%	....
Chimney gases	....	12.0%
Air leakage through walls	9.5%	....
Air leakage through fuel	9.5%	....
Improper draft	3.5%	....
Steam leaks	1.0%	....
Friction in piping	....	3.7%
Condensation	....	2.5%
Exhaust	....	26.0%
Engine Friction	....	4.0%
Transmission	....	1.6%

Fitting of a plant to use the most available materials is frequently a matter which involves considerable expense, and should be attempted only after the most careful and searching investigation, which investigation should be undertaken before the plant is built, if possible, and revision should be made only after it is quite certain what material is, on the whole, the best for efficient operation.

This brings us to the question of what is efficiency? We may define it as the ratio of the actual to the possible, which is sufficiently indefinite to permit of almost any interpretation. The term has heretofore been used largely with regard to energy input and output, but it is as appropriate to fitness and capacity as it is to energy. If one method of distributing the load on machines gives considerable underloading, while another method gives nearly a normal load, the efficiency of the loading is the ratio of the power which will be delivered for a given expenditure of fuel under the worse method to that delivered with the best. By this method of defining efficiency, the efficiency of a method may be dependent on a good many things besides the method itself; evidently getting at efficiency in a series of operations or in a man, is a much more difficult and complicated matter than determining the efficiency of a machine.

To secure efficiency means the elimination of waste; reduction of losses of material, losses of energy, losses of time and of effort, and involves tests for finding out where such losses occur and devising means to do away with the causes of losses. Some of the most common causes of loss in power plants are poor fuel, impure water, furnaces too small, draft too weak, air leaks in the walls, heating surface too small, bare piping, steam leaks, restricted valve area, bad setting of valves, high back pressure, poor lubrication. These are easy to locate, but many others are not so evident.

When a loss is discovered, it takes a large degree of common sense to tell whether it will cost more to avoid the loss than to endure it; and it takes still more common sense to tell which of several proposed methods of overcoming the loss will be the cheapest in the long run. As in everything else, it often happens that the greater first cost will result in the lowest final cost.

Testing should be of 2 sorts, one to determine the efficiency of different pieces of apparatus and of the plant as a whole, in order to check against standards of performance or guarantees made by manufacturers, and the second to discover losses of pressure, draft, friction, etc.

It is important to know whether each piece of machinery is doing better or worse than it did last week, last month, or last year, and how much. Here the records must answer. Testing will show present performance. Comparison with past records shows improvement or decline. Study of detail records must show where and why.

In every factory it is important that each machine and each man shall show some profit if the business is to succeed, and the same is true in the power plant. It is, therefore, essential that an account be kept with each machine, to show the expense of operation, the cost for supplies, repairs and renewals, and on the other side of the account, a credit for the output which it produces.

Good engineering consists in getting a desired result for the least expenditure of money and effort, so that the cost per unit of output is the final basis for deciding on the successes of engineering operation. For power plant service, such basis for comparison may be horsepower-hour, kilowatt-hour, 1000 B.t.u., or 1,000,000 gal.

RESPONSIBILITY CHART

CHIEF	Boiler Supt.	Coal Pile	Receipt, Storage and Coal Handling	Coal Passers.
		Water Supply	Treatment, Heating and Feeding	Water Tenders.
		Feed Pumps	Condition, Efficiency and Operation	Maintenance Men.
		Draft	Stacks, Gas Passages and Blowers	Water Tenders Maintenance Men.
		Boilers	Grates, Heating Surface and Firing	Firemen. Maintenance Men. Firemen.
	Steam Engineer	Piping	Leakage, Friction, Radiation	Maintenance Men.
		Drainage	Drips, Separators, Traps	Maintenance Men.
		Engines and Turbines	Operating Men.	
		Lubrication	Operating Men.	
		Condensers and Pumps	Operating Men.	
		Heating System	Maintenance Men.	
		Water Supply to House	Maintenance Men.	
		Fire Protection	Maintenance Men.	
	Electrical Supt.	Transmission	Maintenance Men.	
		Switchboard	Operating Men.	
		Generators	Operating Men.	
		Motors	Maintenance Men.	
		Batteries	Operating Men.	
		Lamps	Maintenance Men.	

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pumped, but in any case the cost per unit adopted, is the final test of engineering and the comparison of the cost in the plant as operated should be made, against the cost from other plants and the best performance on record in any plant.

In order to get anything done, someone must be responsible for it. The old saying, "What is Everybody's Business is Nobody's," is as true in a power plant as anywhere else, and for smooth and efficient operation, each part of the routine and of the plant equipment must be under the care of somebody who is held responsible for it. In dividing the work of the plant, planning is for the chief executives; supervising is for the lesser executives, and executing the work is for the force. If the plans are wrong or are missing, it is the fault of the chief; if the work is not properly assigned and checked up, it is the fault of his assistants; and if the work is not well done according to instructions, it is the fault of the force. There should be no shirking of responsibility or question as to where the blame belongs for any

miscarriage of proper operation. Those in authority are responsible for furnishing the brains, and it takes a whole man to be a real executive, to pick the man for each job, to assign him to work that he can do best, to teach him the best method of doing his work, and to lead and encourage him to be on the way toward something better. Devising and putting into operation a plan which rewards successful effort and which produces results, is the most important part of efficient management, which is absolutely essential to efficient operation.

"Keeping Tab" In Industrial Plants

INFORMATION TO BE SOUGHT UPON TAKING CHARGE, PROVING VALUE OF NEW MACHINERY, RECORDS AND CURVES. BY P. LUNDELEY

IN operating engineering the former goodly amount of guesswork, at the foundations of the statements given out by engineers in charge of the plants, relative to results obtained, will give way as a matter of evolution to reliable figures and facts arrived at by a thorough system of "keeping tab" on every phase of operation.

The chief engineer, being given the responsibility and the power to act, will gather from the first day he assumes charge, careful data on every piece of machinery and apparatus under his charge and store it up for future use. He will find it necessary to aim at definite and accurate data for 2 purposes: Those enabling themselves to determine without hesitation on any matter pertaining to the maintenance, operation and efficiency of a certain piece of machinery when required; and those which will lead up to the determination of cost per unit of steam, electricity, air, water, refrigeration, etc., required by the office of manager.

The first will include all principal dimensions, and sizes of the different boilers, engines, generators, pumps and working machinery, of whatever description, diameter and length of boilers, grate area and heating surface, diameter and length of tubes, area over bridge-wall, diameter and height of chimney and sizes of the various piping connected to boilers, and the principal dimensions of feed pumps. In engine room, diameter and stroke of all reciprocating pumps, usually found stamped by manufacturer. Size and speed of centrifugal pumps, of all engines' cylinder diameters and stroke, and sizes of packing for reciprocating rods and spindles. Valves, correctly set, should be trammed, and the right amount of clearance at both ends of cylinders carefully adjusted. This is particularly important on tandem engines.

NEW MACHINERY

ON INSTALLING new machinery, the results of the initial trials should be recorded, and filed for future reference, as well as drawings or prints if obtainable. It will be found of value and save loss of time to be able, at any moment, to decide the conditions under which a boiler, engine, pump or other apparatus worked when new, for comparison with later tests and trials.

The operating engineer will usually find it tending to increase the efficiency of the men and thereby the plant, in establishing a system of daily records kept by the men in charge of the various departments, dealing with every important factor relative to the equipment they are handling, the chief fireman or boiler-room foreman keeping accurate account of every pound of coal burned, ashes taken out and water evaporated, by scale and meter.

These data are, of course, absolutely essential as the very basis on which to arrive at the real results obtained. Likewise important is the continuous record of the feed-water temperature. An inserted thermometer in the feed line will make this easy. An intelligent boiler-room foreman will, with the necessary devices, usually interest himself in securing all this information, as it adds to the feeling of responsibility, perhaps dignity. On his records should also appear, at certain intervals, at least, temperature of flue gases, as well as readings of the draft gage; the time each boiler has been in operation; when cleaned and inspected, and any defects, leaks, etc., discovered.

The periodical visit of the boiler inspector should be welcomed and of interest and benefit as well to the boiler-room foreman as to the chief engineer, and his advice duly considered.

VALUE OF RECORDING INSTRUMENTS

THE RUNNING engineer should fill out a form giving all necessary information about the conditions under which the machinery under his care is working. Here is where recording instruments will be found advisable, these to be placed on all pressures on steam and exhaust of engines, on ammonia and air-compressors, recording tachometers on engines working at variable speeds, etc. Knowing that there will be a curve to tell the tale, it will, for instance, tend to have the air-pump attended to immediately if vacuum fails, while otherwise a certain amount of extra coal might have had to be burnt for awhile. Recording instruments should be especially valuable where there is a continuous day and night operation, for obvious reasons.

Where there are a number of different departments using steam and electricity for manufacturing purposes, it will generally pay to install meters and instruments for measuring the consumption. In large industrial plants of various kinds, water is often used in great quantities and its pumping is a matter of no small importance. By placing meters on the lines to the different departments, it can be checked against the total amount pumped from well or other source. It will often be a surprise to all concerned, to know exactly how much water is really being consumed.

The "keeping tab" must be progressive, beginning in the boiler room; detailed information gathered from

the various departments, to where the products of the power plant are being distributed for use and returning to the chief engineer's office.

Unit Costs

To arrive at the cost of a boiler horsepower-hour, knowing the amount of water evaporated per pound of coal, to this must be added the cost of operation of the boiler room, materials, repair and maintenance, the proportional amount of administration expenses, and interest, as well as a fair percentage of depreciation of buildings and equipment.

By intelligent use of the indicator, the consumption of steam of the various engines and generators will be arrived at, and fairly accurate constants determined on to simplify the daily calculation of the amount of steam used per unit of the output of the various machines, as kilowatt-hour of electricity, tons of refrigeration, cubic feet of air and water per brake-horsepower hour. To these items must, of course, be added as in boiler room, a certain proportion of the several expense burdens, as named in that connection.

This record keeping will be made easier by the use of printed blanks for all purposes, all aiming at the finished result at the end of the month, when a resume of the daily log, in concise form, should be made out for the manager's office to give him the needed data, in determining the cost of the different processes of the manufactured products.

There is a daily education in "keeping tab," the value of which has rarely been appreciated, either by employer or operator. The latter will find that the more means and devices he equips the plant with for this purpose, the more he realizes how little he really did know before of what was going on, and how throwing light on one subject will usually lead to the discovery of another hitherto unnoticed source of waste or opportunity for economy.

A simple card system may be established for the keeping of consumption of fuel and material, as well as over repairs, and cost of labor.

By giving each piece of machinery a number, the factory being again divided into different departments, it will be possible to keep track of these data, with a moderate amount of office help. All the monthly record sheets should be filed for comparison from month to month and year to year.

Checking Operating Conditions

In plants where numbers of electric motors are in use, readings should be taken at certain intervals, or when undue sparking and heating up is taking place, to see that they do not carry depredatory overloads. On centrifugal pumps working on variable loads there is room for a good deal of argument as to the best way of running them, and when motor-driven this can be best ascertained by taking readings of the current while experimenting with suction and discharge valves to find the most economical load within its purpose. A water meter will always furnish an excellent check on the proper working of a pump, its capacity when installed being known. The ammeter on a triplex pump motor will indicate which plunger or set of valves is out of order.

To check the water meter for the boiler-feed some means should be provided. If the pumps get the water from a tank, whose area is known, readings of the meter and fall in tank may be taken simultaneously for comparison. As the meter is apt to be a little off one way or the other, this amount should be added to or deducted from the daily meter readings as the case may be.

To determine the efficiency of condensing plants and cooling towers, temperatures should be taken of water entering and leaving towers, preferably by providing the pipes with inserted thermometers. There is often an undue amount of waste taking place in this part of the plant, and considerable economy may be obtained by proper investigations and experiments. Where scale-forming water is used, piping must not be allowed to fill up too much, as this soon will reduce the capacity and increase the friction head of pumps. Another item often unheeded is the wasted exhaust steam from pumps, small engines, traps, etc., which might be profitably used in heating feed-water.

All reports from men in charge of departments, however seemingly insignificant, should be attended to or considered, in order to encourage them in giving attention to the little things as well. In changing from hand to mechanical firing, the man in charge should realize from the start, that this does not mean a sinecure for him and his crew, the latter as a matter of course, being reduced in numbers, as the fuel feeder or mechanical stoker needs diligent attention. The top of the smokestack while not a CO_2 recorder, provides a persistent indicator of the management of the fires under the boilers.

Any device to record the continuous handling of any apparatus will act as a check on the labor and help to insure uniform operation. In large industrial plants where a machine shop is a part of the equipment for carrying out repairs and changes, a technical assistant to do the necessary drafting, if added to the force, would be the proper person to be entrusted with the keeping of the operation-records and perhaps with the supervision of all recording or indicating devices and instruments.

Such plants covering large areas, often have a network of underground piping. It is essential to have an accurate plan of this to be kept up to date by drawing in new lines and eliminating obsolete ones, new prints being made when any marked alterations have taken place. This will save a great deal of trouble and labor.

The engineer as well as the manager would perhaps find it worth the expense making out a graphic chart, dividing the year into quarters, these into months and these again into days, showing a continuous curve of fuel-consumption, evaporation of water and output of products. It always tells a very interesting story at the end of the year.

These may be traced and prints made for the engineer's and manager's office. The latter will sooner or later realize that the chief engineer given the authority

and assuming the responsibility with increasing interest will work for the benefit of the plant under his charge, when he sees that he is gradually gaining the confidence of his employer by proving that up-to-date methods, even at the outlay of some money in first cost, are the most economical in the long run.

A wide-awake operating engineer, with a broad experience in other plants, knowing every detail about his plant, seeing its shortcomings and possibilities and daily studying and learning new facts and features of its various branches, will finally prove himself to the manager, as the best consulting engineer he could employ.

Recording Instruments

CHART RECORDS A GUIDE FOR THE IMPROVEMENT OF POWER-PLANT ECONOMY. CONSTRUCTION OF PRESSURE AND TEMPERATURE RECORDERS AND FORMS OF CHARTS

ASIDE from the permanent data provided by recording instruments, from which power-plant conditions may be thoroughly analyzed by comparing simultaneous records, accurate data are also furnished in experimental or testing work, showing variations which often cannot be covered by observations taken periodically. Since pressures and temperatures of steam, water, air, and gas are the factors most frequently involved in power production, the value of recording gages and thermometers is at once apparent.

Recording gages consist essentially of 3 parts, a moving element, a pen, and a clock movement. For pressures above 3 lb., the moving element usually consists either of a circular tube of oval cross-section in the form of a helix, or of a metallic Bourdon tube. For pressures less than 3 lb. a more sensitive device in the form of a diaphragm is used.

Ordinarily the recording arm, which carries the pen, is attached directly to the moving element, without multiplying devices. The pen, which is made of some noncorrodible material, is filled with ink and traces a permanent record upon the chart.

By means of the clock movement, the record sheet or chart, which is carried on a disk or drum mounted on the clock spindle, is moved at a uniform speed.

Two forms of charts are used, the circular chart mounted upon a disk, and the drum chart carried on a cylinder, the disk or drum being made to revolve in any desired period. Drum charts may cover short periods, such as 24 hr., or be continuous. Two drums are required for the continuous chart, the paper being wound from one to the other so that a single record may cover a period of several weeks.

Where circular charts are used, the pen arm is usually pivoted near the edge of the disk so that the pen moves in a radial arc. Hence the chart graduations consist of radial arcs corresponding to the hours of the day and concentric circles, which represent the pressures or other values measured by the instrument. On circular charts where the pen travels in a straight line, radial lines take the place of radial arcs. On drum charts the lines representing the values measured are straight and perpendicular to the axis of the drum, while the time lines are circular arcs or straight lines, depending upon the movement of the pen.

As in recording gages, the moving element of recording thermometers consists of a helical tube or diaphragm, the gages being similar in all respects. In the case of temperature, a sensitive bulb, ordinarily filled with a volatile liquid or gas under pressure, is inserted at the source of heat and connected to the recording instrument by means of a flexible capillary tube, which is usually protected by a suitable covering. The expansion or contraction of the vapor or gas enclosed in the bulb and connecting tube, produces a movement of the pressure tube which is communicated to the pen arm as in the recording gage.

American Recording Gage

AMERICAN STEAM GAUGE & VALVE MFG. CO.

IN the illustration is shown an interior view of this gage from which it will be noted that the moving element is a large Bourdon tube, whose motion is transmitted to the pen arm by a system of levers. No gears are used and adjustment is made by means of the slotted links.

For tracing the records a fountain pen is used, which will mark for a long period with one filling of ink.

ILLUSTRATION SHOWING MECHANISM OF RECORDING GAGE

Another type of this gage is the duplex recorder which combines 2 gages in one and registers 2 distinct pressures on one chart. By the use of this gage 2 entirely different pressures may be recorded, as each recording arm is connected with a separate spring and movement and acts independent of the other. The chart makes a ½ complete revolution in 24 hr., recording the different pressures on each half of the chart so that one will not conflict with the other.

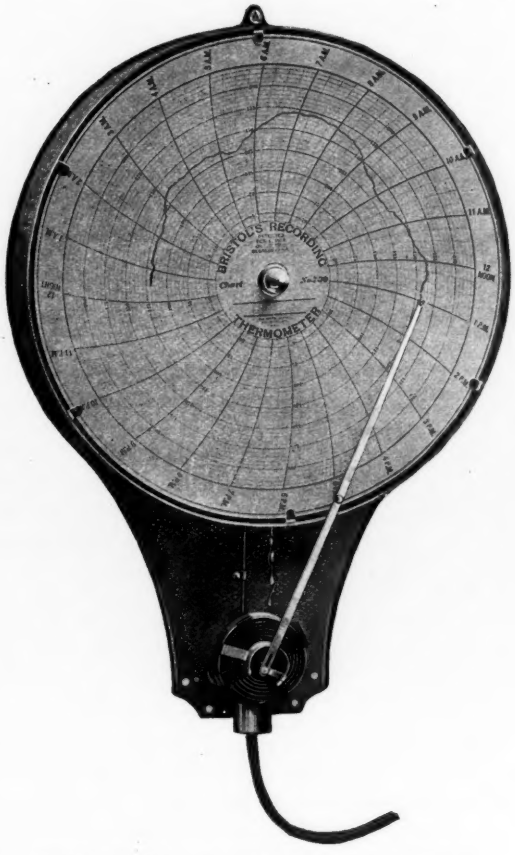
Bristol Recording Thermometers

BRISTOL CO., WATERBURY, CONN.

IN construction, this instrument is almost identical with the Bristol recording pressure gage, the moving element consisting of a helical pressure tube to which the recording pen arm is attached directly. For low ranges of temperature the pressure tube is wound in

the form of a spiral, as shown in the cut, and is equipped with a patented compensating device which makes these thermometers independent of changes of temperature at the recording instrument, as shown in the figure.

These thermometers depend, for their operation, upon the pressure due to the expansion of a liquid, vapor or gas, contained in a bulb, the bulb usually being connected to the recording instrument by a flexible copper tube 25 ft. or more in length. The liquid-filled type is listed for temperatures up to 150 deg. F., the vapor-filled type for temperatures between 90 deg. and 500 deg. F., and the gas-filled type for temperatures from 60 deg. F. to 800 deg. F. Where vapor is the medium



SPIRAL FORM OF PRESSURE TUBE EQUIPPED WITH COMPENSATING ATTACHMENT

used to transmit the pressure due to expansion, the bulb is partly filled with a volatile liquid such as alcohol, while in the gas-filled type the bulb and tube are filled with a gas under pressure. In the gas-filled type the varying pressures due to the expansion of the gas in the bulb are proportional to the changes of absolute temperature at the sensitive bulb. The liquid and gas-filled thermometers are equipped with charts uniformly graduated over the entire range, while the vapor-filled type gives increasing scales due to greater vapor tension for a unit degree change at higher temperatures than at lower ones. The flexible copper capillary connecting tube, which is usually provided with a flexible protection consisting of a steel or bronze armor, is of sufficient length to permit the installation of the recording instrument at a considerable distance from the point where the temperature is to be measured. The gas-filled instrument may be installed above or below the sensitive bulb without affecting the accuracy of the record, and the vapor-filled type can be calibrated for any desired position.

These instruments are adapted where permanent records of the temperature of boiler feed-water, flue gases, etc., are desired.

Bristol Recording Gages

BRISTOL CO., WATERBURY, CONN.

FOR pressures exceeding 3 lb per sq. in. a helical tube of flattened cross section untwists an amount proportional to the pressure applied, transmitting its motion directly to the pen, as illustrated in Fig. 1. For minute pressures, a diaphragm or bellows-shaped tube is employed, the tendency of the tube to elongate upon the application of pressure being resisted by an elastic metal strip on one side. The pen arm is attached directly to this diaphragm tube and multiplies the resulting angular motion as shown by Fig. 2.

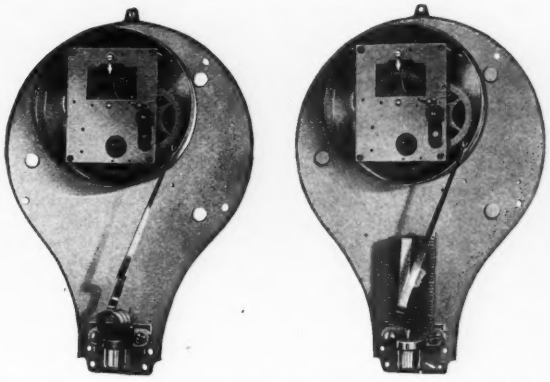


FIG. 1. MECHANISM OF HIGH-PRESSURE RECORDING GAGE
FIG. 2. MECHANISM OF LOW-PRESSURE GAGE

The recording arm in both types of gages is attached directly to the moving element, thus rendering the mechanism simple. These helical tubes are made with several coils, giving ample motion without undue strain on the tube, likewise the diaphragm is of sufficient length to give the pen ample motion.

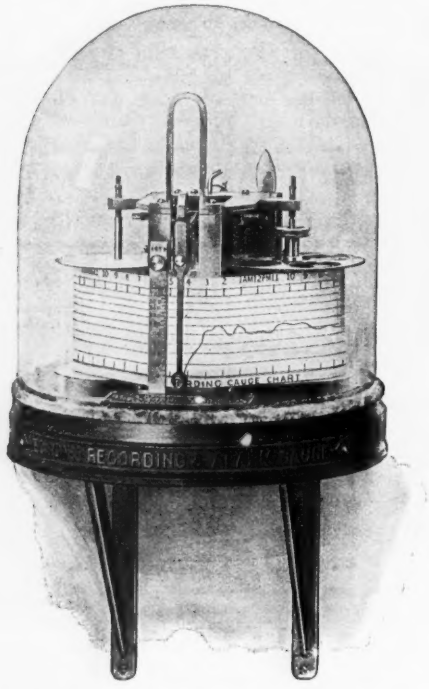
All of the commercial pressure and vacuum ranges are covered by these gages, which may also be furnished in the portable form (and the round shape). Gages for recording drafts are equipped with a form of pressure tube which is both sensitive and positive in action. These gages are calibrated for ranges of 0 to 1 in. of water and lower, the charts being graduated to 0.02 in., so that it is possible to record slight changes in draft conditions. In addition to these gages, a differential gage is made which measures differences of pressure, such as those encountered in the measurement of the flow of steam and water with Pitot tubes and Venturi meters.

Edson Recording Gage

ASHCROFT MFG. CO., NEW YORK

IN this recording gage, shown by the figure, the mechanism is actuated by a corrugated diaphragm of tempered steel, carefully treated by a special process.

This steel diaphragm is protected by noncorrosive metal lining and is placed horizontally within a recess under the supporting base of the gage, being enclosed by a concave iron cap, so secured at its outer edge as to form a steam-tight chamber beneath the corrugated diaphragm. Pressure is admitted at the center of the iron



EDSON RECORDING GAGE WITH GLASS CASE

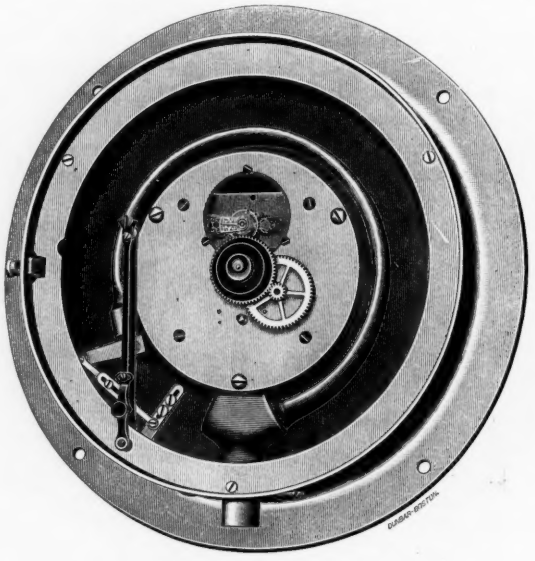
cap and causes the deflection of the diaphragm in proportion to the pressure applied. The pressure is read on a vertical scale, which is accurately graduated to correspond to the diaphragm of the instrument.

On a rectangular chart the record is traced by a metal marking point, made either of lead or silver, the latter being used with chemically-prepared record sheets, producing a very fine line. This gage, which can be used for pressures up to 500 lb., may be fitted with alarm for high and low pressure, as desired. The entire mechanism is covered by a glass case, resting on felt, to protect the instrument from dust.

Crosby Pressure Recorder

CROSBY STEAM GAGE AND VALVE CO., BOSTON, MASS.

AS shown in the figure, a Bourdon tube forms the moving element in this gage, the movement being transmitted to the pen arm by a system of levers. The tube is made by a special method, and screwed to the socket and tip by threaded joints without the use of solder, thereby insuring durability, accuracy of operation and permanent calibration. The socket, by which the gage is attached to the boiler, extends upward within the case and supports the clock and other operating parts, thus giving a record true to the axis of the chart under all conditions.



CROSBY RECORDER WITH FRONT AND DIAL REMOVED, SHOWING MECHANISM

On the same pinion with the pen lever and below it, is a corresponding lever carrying a small table on which rests the pen. As the chart is placed between the pen and table, each one bearing upon it, a continuous contact is made insuring an unbroken line. The chart divisions are equally spaced.

By means of an ingenious device at the base of the pen arm, the pressure of the pen on the chart can be suitably adjusted. This instrument may be used for any ordinary pressure.

THE NEW CROSSCUT POWER HOUSE will be built by contract and the reclamation service is requested to complete at once the reconstruction of the transmission line from Roosevelt to Phoenix, Ariz., though the protest of the governors against the project being charged up with the cost of reconstruction still stands.

These are the principal results of the recent meeting of the board of governors with Frederick H. Newell, director of the reclamation service, Consulting Engineer D. C. Hanny and Electrical Engineer O. H. Ensign.

For some time a controversy between President John Orme, of the W. U. A., and the government regarding the manner in which the New Crosscut plant shall be constructed, has been on. President Orme wanted to let a contract. Engineer Ensign protested that it was impossible to draw a set of specifications for the placing and adjusting of the generating machinery that would insure everything being exactly as it should be. After much conferring he said that he would draw as accurate a set of specifications as possible. Bids will be advertised for when the specifications are approved.

Foxboro Recording Gages and Thermometer

INDUSTRIAL INSTRUMENT CO., FOXBORO, MASS.

IN this instrument the helical tube movement, Fig. 1, is used for pressures greater than 10 lb. per sq. in. Pressure applied causes the tube to untwist and the free end to move a distance proportional to the pressure applied. In this tube a simple but substantial support has been devised which supplies an axis of rotation resulting in the precise travel of the end over a definite, predetermined arc.

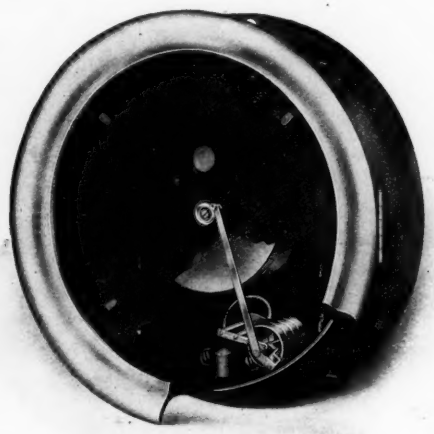


FIG. 1. INTERIOR OF GAGE SHOWING HELICAL TUBE MOVEMENT FOR HIGH PRESSURES

A pen arm is attached directly to the shaft shown through the center of the helix, and is supported at both ends. This shaft is connected to the free end of the tube by a special connection which is flexible only in the direction of the radial expansion of the tube. This construction eliminates multiplying devices and also the possibility of accidents.

FIG. 2. DIAPHRAGM TUBE MOVEMENT FOR LOW PRESSURES

Any adjustment of the pen arm will not change the effective length since the action of adjustment coincides with the axis of motion of the pen. The pen and arm are made of German silver, reducing the possibilities of corrosion to a minimum.

For pressure below 10 lb., a form of diaphragm tube, Fig. 2, is used. This consists of a series of diaphragms built up into the form of a bellows. Application of pressure tends to elongate the tube, but the motion is converted into a multiplied lateral motion by the means of the restraining coils, secured to the side of the tube. The restraining coils reduce the number of diaphragms formerly used and with special mounting, similar to that used in the helical tube motion, give a rugged construction.

When removed, Fig. 3, the tension head leaves a flush surface on the dial, so that changing the chart does not disturb the pen or any other working part. A slight turn of the tension head to the right releases

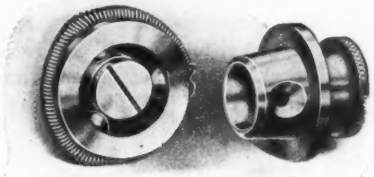


FIG. 3. AUTOMATIC, SELF-CENTERING FLUSH CHART HOLDER

it from position, and, as it is tapered, the chart automatically centers when placing it back in position.

In addition to the recording pressure gage is the differential recording gage which is designed to record the difference between two existing pressures in any range from 4 in. head of water up. It is especially adapted for measuring the flow and volume of liquid and gases by means of Venturi and Pitot tubes. For pressures below 10 lb. the diaphragm tube is used, while for

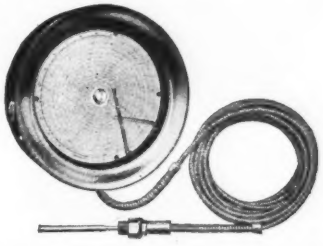


FIG. 4. RECORDING THERMOMETER WITH CONNECTING TUBE AND BULB

pressures greater than 10 lb. the helical tube is used. One of the 2 pressures, the difference between which is to be recorded, is applied internally to the pressure tube, the other externally. In this manner the action of the tube is produced by the difference between the 2 pressures. The motion is transmitted by a shaft through the walls of the chamber, which has a special bearing, to the pen arm, the arrangement of which is the same as in the pressure recorder.

The Foxboro recording thermometer depends for its action upon a measurement of pressure by the expansion of a liquid, the pressure of saturated vapor of a volatile liquid or a pressure caused by the expansion of gases. For temperature ranges up to 400 deg. F., a cylindrical bulb, partly filled with a volatile liquid is used. Leading from this bulb to a helical tube is a fine bored capillary tube which gives free passage to a vapor that arises from the surface of the fluid when heat is applied to the bulb.

In effect, the helical tube is a series of Bourdon tubes, end to end, and the expansion is the same as in a Bourdon tube.

Precision Recording Gages

PRECISION INSTRUMENT CO., DETROIT, MICH.

IN the measurement of pressure, this instrument employs the principle of the Boudon tube. In Fig. 1, will be seen the construction of the lever arrangement or 4-bar mechanism which compensates for the inequalities of movement of the tube, making the readings dead accurate from zero to full stroke.

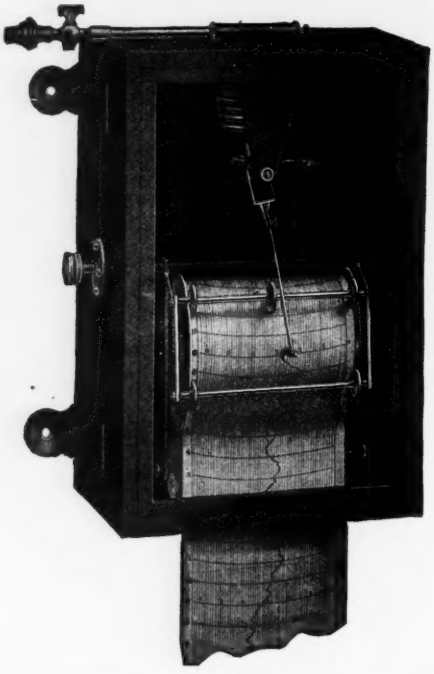


FIG. 2. CONTINUOUS TAPE RECORDER FOR LOW PRESSURES

Variations in pressure are transmitted by the movement of the tube through a vertical adjustable plunger which is attached to a horizontal shaft by means of a link or lever of adjustable length. This shaft is supported by a bracket and is normal to the plane of the chart's disk, converting the reciprocating motion of the pressure tube to rotary motion. The pen arm is suspended from the shaft and at right angles with it, so that when the shaft revolves, the pen arm moves parallel to the chart, keeping the pen in delicate but constant contact. There are 5 main adjustments which enable the movement to be calibrated to accuracy at every division of the chart. Since the shaft is suspended on point bearings, it is practically frictionless, the low-pressure gages being so sensitive that it is necessary to equip them with a damping cock shown between the bottom of the case and the shutoff cock.

For the measurement of low pressures or vacuum, the same mechanism is used, except that a diaphragm takes the place of the Bourdon tube in the high-pressure recorder. Although the pen is extremely sensitive, it comes to rest at once, showing the pressure or vacuum instantaneously.

FIG. 1. FRONT REMOVED SHOWING DIAPHRAGM AND MOVEMENT OF LOW-PRESSURE GAGE

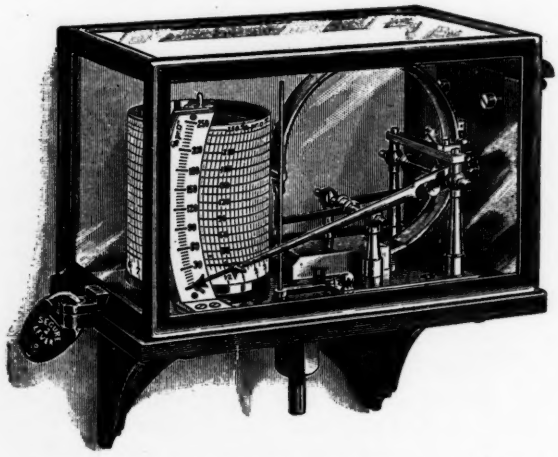
Pressures and vacuum recorders and indicating gages can be furnished in the portable form, covering all the ordinary pressure ranges. Figure 2 shows the continuous tape recorder, which is built for high and low pressure or vacuum.

Metropolitan Recording Gages

SCHAEFFER AND BUDENBERG MFG. CO., BROOKLYN, N. Y.

AS shown by the illustration, this gage depends for its operation upon the action of the Bourdon tube. By means of a set of cranks, pins and levers, the movement of the tube is transmitted to a long arm fitted with a pen which records the pressure, and an extension pointer which moves over a graduated scale, indicating the pressure.

Since the chart drum is 5 in. in diameter and gives the chart a speed of about ½ in. per hour, small fluctuations in pressure may be easily observed.



METROPOLITAN RECORDING GAGE WITH GLASS COVER

For the purpose of protecting the instrument from dirt, a glass cover is placed over it, at the same time leaving all parts exposed to view.

Columbia Recording Gages

SCHAEFFER AND BUDENBERG MFG. CO., BROOKLYN, N. Y.

IN this gage, Fig. 1, the Bourdon type of spring is used for pressures over 8 lb. The motion of the spring is directly transmitted to the pen arm by means of a lever, thus permitting of delicate adjustment and insuring accuracy. For recording pressures less than 5 lb. and as low as 1/10 in. head of water, special diaphragm springs are combined in such a manner as to be quite sensitive.

Figure 2 shows a new type of pen arm which facilitates the chart-changing operation. The pen arm is lifted from the guilding pin and pushed aside, thus clearing the space for changing the chart. There is also an adjusting arrangement in the pen arm by means of which the gage can be readily adjusted for height of water column when the recorder is mounted below the boiler connection.

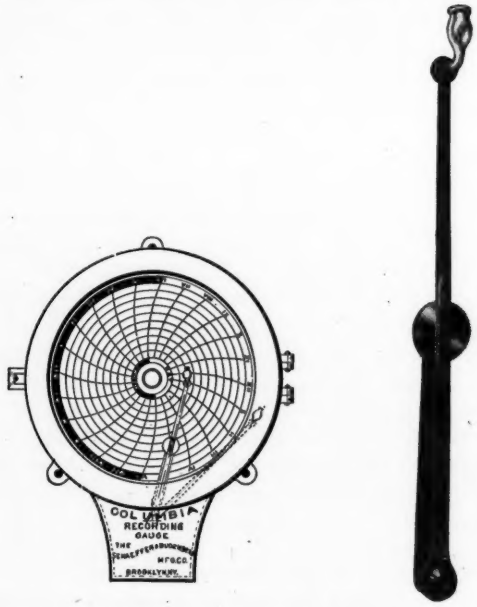


FIG. 1. COLUMBIA RECORDING GAGE
FIG. 2. S. & B. RECORDING PEN ARM SHOWING ADJUSTING ARRANGEMENT

Tycos Recording Gages

TAYLOR INSTRUMENT COMPANIES, ROCHESTER, N. Y.

THESE thermometers operate by the expansion and contraction of mercury in a steel tube system of practical and strong construction which insures great sensitiveness and at the same time eliminates delicate features.

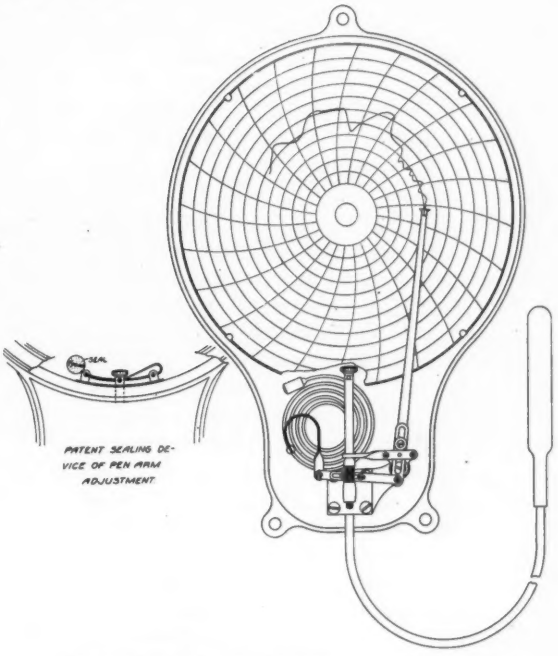


DIAGRAM SHOWING INTERIOR OF RECORDER

As the flexible capillary connecting tubing is practically indestructible, no outer protecting sleeve is required. The plain bulb capillary form is designed for enclosed spaces where operating conditions necessitate locating the bulb a considerable distance from surrounding walls; however, bulbs can be furnished with any form of connection desired. Charts for this instrument are graduated up to 1000 deg. F., the graduations being uniform, owing to the fact that the co-efficient of expansion of mercury is constant for any change of temperature.

In the illustration the mechanism of the recorder is shown. By means of a patent sealing device, adjustment of the pen arm by unauthorized persons is prevented.

Water and Its Treatment

COMMON SCALE FORMING IMPURITIES, OIL IN BOILER, COOLING WATER, MATERIALS USED IN TREATMENT

FOR power plant use, the chief requirement in a water is that it shall be free from scale-forming material, as such material will make trouble whether the water be used as a feed for boilers or as cooling water for condensers. Scale in a condenser is often quite as serious a problem as in the boiler, although not as dangerous.

Almost any form of mineral matter which can be carried in solution is troublesome, but the chief "pests" are sulphates and carbonates of lime and magnesia. This is partly because they are the most common scale-forming material, partly because, under the conditions of use in a boiler, they are the ones most likely to form hard scale which is difficult to remove and which bars the transmission of heat.

Acids and animal or vegetable matter in the feed-water are likely to cause pitting and corrosion in a boiler, but are not of so great consequence in cooling water, as there is not time for them to act, and the tubes through which they pass are not as subject to corrosion as the boiler shell.

Oil in feed-water to a boiler is bad. Spite of the fact that kerosene and sometimes crude petroleum are advocated as preventives of the adhesion of boiler scale, there seems to be more evidence of damage done than of beneficial effects. In any case, oil used intentionally is in quite different condition from that which may be brought in with condensation from the exhaust, which has been emulsified, and is, therefore, in condition to form a nonconducting scale when it is combined with the incrusting materials of fresh feed-water.

It is possible to get a water too pure. If water has no mineral in solution, it is seeking such mineral and will attack any weak spot in the boiler shell, tubes or piping, taking up a certain amount of iron or steel particles and carrying them away with it. For this reason, the use of rain water is generally not good; rain water is also likely to contain a certain amount of acids which it has absorbed in its passage through the air, and these will tend to increase the corrosive effect.

For cooling water, it is necessary that the temperature at the intake to the condenser shall be a reasonable amount below the steam temperature of the condenser, if satisfactory results are to be secured. Too high an inlet temperature means either a very large volume of water to be handled or insufficient vacuum. As an index to what will prove satisfactory, the following figures will serve: For 29-in. vacuum, inlet temperature 60 deg. or under; 28.5 in., 70 deg.; 28 in., 80 deg.; 27.5 in., 88 deg.; 27 in., 94 deg.; 26.5 in., 100 deg.; 26 in., 104 deg.

Where water from river or pond is used in condensers, there is not much possibility of changing the inlet temperature; but where, as is frequently the case, the water comes from cooling towers, provision should be made to maintain inlet temperatures of the cooling water not higher than those given. Of course, the lower the inlet temperature, the less will be the volume of water required and the less the expense for handling it.

Treatment of water for boiler feed should include the neutralizing of any acids which may be present, filtration where necessary to remove suspended matter, and treatment for the incrusting minerals in solution, either to precipitate them before the water enters the boiler or to cause precipitation in the boiler in the form of a mud or sludge which can easily be blown out.

The most common treatment consists of heating the water, of chemical treatment, or a combination of the 2. Heating to a temperature of 212 deg. drives off the carbonic acid gas on which the holding in solution of the carbonates depends, so that frequently, if carbonates form the chief solids in solution, heating to this temperature will be sufficient to throw down the solids in the feed-water heater. Where sulphates are contained, it is necessary to heat to 290 deg., when a large part of the incrusting material will be deposited. For chlorides, a temperature of 340 deg. must be reached. In any case, heat treatment alone will not throw down the entire amount of the impurities, but will generally take out sufficient so that the remainder will not be excessively troublesome.

Where chemical treatment is used, the chief constituents are lime and soda ash, but it is not a scientific thing to use these without knowing what the water contains, and this must be determined by careful chemical analysis. The directions for an elementary analysis are given in another article, but where there is any question as to the correctness of such analysis, or the presence of impurities that cannot be detected by it, a sample should be analyzed by a competent chemist.

As determining what water may be considered unsuitable for boiler use, G. C. Whipple gives the following classifications: Up to 10 parts of scaling solids in a million parts of water, very soft; 10 to 20 parts per million, soft water; 25 to 50 parts, slightly hard; 50 to 100 parts, hard; 100 to 200, very hard; 200 to 500, excessively hard; 500 or more, a mineral water. Soft or very soft waters may be used without serious inconvenience if they are not treated, requiring only infrequent removals of scale from the boiler. Above that the difficulty from incrustation will increase rapidly with the amount of incrusting solids, and will need treatment of some sort in order to keep the boilers in efficient working condition.

As an index for the amount of chemical needed in treating feed-water, the following table will serve, the weights given being the number of pounds to be added to a million gallons of water for each one part in a million of the impurities named: Free carbonic acid present, add 10.62 lb. of lime; free acids present, add

4.77 lb. lime, 9.03 lb. soda ash; alkaline solids, add 4.67 lb. lime; incrusting solids, add 8.85 lb. soda ash; magnesium, add 19.48 lb. of lime. Thus, if the incrusting solids analyze as 50 parts in the million, which would indicate a hard water, we should add $50 \times 8.85 = 442.5$ lb. of soda ash per million gallons of feed-water.

This addition will cause the incrusting solids to be thrown down as porous scale or a soft sludge. This, since the water can penetrate it, does not usually have serious effect on the efficiency of the boiler, as determined by the experiments of Prof. R. C. Carpenter, but the material should be frequently cleaned out, and if any oil is present, it may combine with this porous material to form a hard scale which will cause damage, as well as reducing the efficiency seriously.

Testing Water Supply

Analysis of Water to Determine the Presence of Most Common Impurities and Give an Idea of the Amount Present

IT can hardly be expected that the power plant engineer shall be an expert chemist as well and do all the chemical analyses which may be desirable for the best operation of the plant, but he should by all means understand the principles involved and have at hand some method of checking up on his chemist which will be simple and easily applied.

For this reason we give herewith a few of the important tests which can be made quite rapidly and with sufficient accuracy to determine the comparative value of different waters which may be available for boiler feed purposes.

Soap Test

Hardness of water is the principal test with which the engineer is interested, because this is the quality which causes scale. The simplest and most common method of determining the amount on percentage of scale-forming material in water is by means of the soap test which was invented by Dr. Clark, who was the first to use a water-softening process.

This test depends upon the principle that a soap solution will cause water to sud when shaken as soon as all the salts of lime and magnesia have become chemically satisfied by the fatty acids in the soap. It is necessary therefore to make, or purchase, a standard soap solution, 1 cubic centimeter of which will neutralize 1 milligram of carbonate of lime in solution. By this means a comparison is made between the hardness of distilled water and the sample tested.

Standard Hard Water and Soap Solutions

When it is desired to make a standard soap solution it is necessary to have a standard hard water solution to determine the accuracy of your soap solution. To make this dissolve 1.11 grams of pure fused calcium chloride in a little water, and dilute to 1 liter at 15 deg. C. Each cubic centimeter of the solution will then correspond to 0.001 gram calcium carbonate.

While castile soap is much used for standard solutions, it is liable to considerable deterioration on keeping, especially in cold weather. For this reason sodium oleate is to be preferred and is generally recommended for the purpose.

Thirteen grams of sodium oleate are dissolved in 500 c.c. of distilled water and 500 c.c. of alcohol and filtered if necessary. To standardize this solution, 12 c.c. of the standard hard water are run into a 250-c.c. stoppered bottle from a burette and diluted to 58.3 c.c. A burette is now filled with the soap solution which is run into the bottle 1 c.c. at a time, and the bottle thoroughly shaken after each addition until a point is reached where a persistent lather, lasting for at least 5 min., is obtained.

Note the volume required. 12 c.c. of hard water should require 13 c.c. of soap solution (distilled water itself requiring 1 c.c. to form a lather), but it will be a figure less than this, and, therefore, the soap solution is too strong and will require diluting, so that 12 c.c. of the standard hard water will require 13 c.c. of the soap solution.

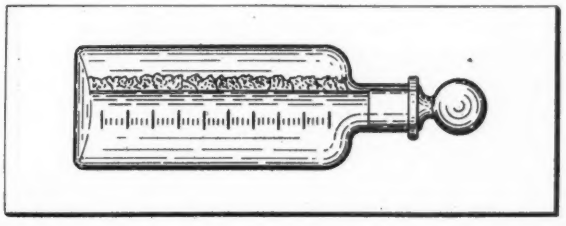


FIG. 1. GRADUATED BOTTLE SHOWING RESULT OF SOAP TEST

For example, 13 grams of sodium oleate were dissolved in a mixture of 500 c.c. of alcohol and 500 c.c. of water and filtered. On testing in the manner described, 12 c.c. of standard hard water, diluted to 58.3 c.c., required 11.4 c.c. of the soap solution to form a persistent lather.

Now, since 13 c.c. should have been required, every 11.4 c.c. of the soap solution left requires diluting by $13 - 11.4 = 1.6$ c.c. Suppose there were 960 c.c. of the solution left, therefore, $960 \div 11.4$ equals 84.2, and $84.2 \times 1.6 = 134.7$ c.c. more of the mixture of alcohol and water to be added. On adding this quantity, thoroughly mixing and testing as before, 12 c.c. of the standard hard water required exactly 13 c.c. of the soap solution.

Testing the Water

To determine the total hardness of the sample, 58.3 c.c. of the clear sample are run into a 250 c.c. flask and the standard soap solution is added in the manner described above until a lather capable of persisting for 5 min. is produced. The number of cubic centimeters required, will give the degree of hardness in terms of calcium carbonate in grains per gallon. The reason for using 58.3 cubic centimeters is that in the United States gallon there are about 58,318 grains, so that for each cubic centimeter of the soap solution required, there is one grain of hardness in the water.

If the water contains a fair proportion of magnesium salt there will be some difficulty in obtaining the right

point, owing to the slowness with which magnesium salts decompose soap. An apparent persistent lather is formed, which, on being allowed to stand a little while and again shaken up, will disappear. A little experience with magnesium hard water will familiarize the operator with this peculiarity.

While the above test will give the total hardness, it is important to know how much of this is permanent, and how much temporary, hardness. This determination can be made as follows: Pour 250 c.c. of water into a 500 c.c. flask and boil for one-half hour, the original volume being kept up by frequent addition of boiled distilled water, free from carbon dioxide. After cooling, it is quickly poured into a 250 c.c. graduated, stoppered flask, diluted, if necessary, to exactly 250 c.c. at 15 deg. C., with distilled water, well mixed and filtered. 58.3 c.c. of the solution are now poured into the bottle and the permanent hardness determined as described.

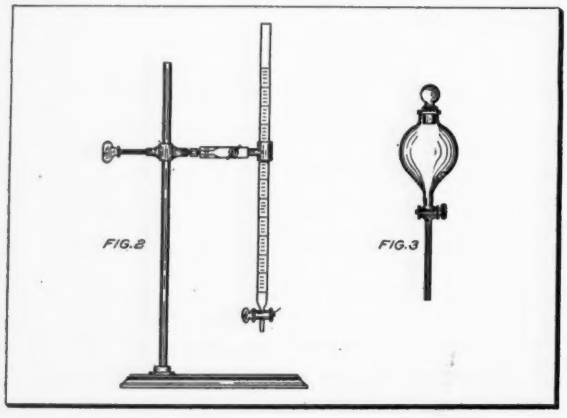


FIG. 2. BURETTE USED IN MAKING SOAP TEST
FIG. 3. SEPARATING FUNNEL USED IN TESTING FOR OIL

The temporary hardness, which is usually the carbonates of lime and magnesia, were deposited when the water was boiled, so that the difference between the permanent hardness and the total hardness would represent the grains per gallon of temporary hardness.

Acid Test

Since it is desirable to know whether the water contains acid or alkali, tests can be made by the use of litmus paper. If the solution is alkaline, red litmus will turn blue; if acid, blue litmus turns red; if neutral, neither changes when a piece of the paper is dropped into the water. This experiment, however, is subject to considerable error, so that the following test is recommended for this purpose.

A standard acid solution is made and a color indicator, usually a drop of methyl-orange is put in the liquid. This solution is a pale lemon yellow when in alkaline liquid and retains its yellow color when acid is added until all carbonates are neutralized, when it becomes pale orange, and any further addition of acid produces a pink or red, depending on the excess of acid added. This experiment, therefore, also shows the hardness of the water, that is, the degree of carbonate present.

For alkalinity the test is made by taking 200 c.c. of water and pouring it into a porcelain basin, after which the measuring flask is rinsed with distilled water and the washings added to that in the basin. Two drops of the methyl-orange are added to the water, and a standard solution of hydrochloride acid, 1/5 normal strength, is put into the basin from a burette, drop by drop, stirring constantly until the liquid changes from yellow to orange and finally to faint pink. The number of cubic centimeters of hydrochloride acid solution used from the burette gives the number of parts of calcium carbonate per 100,000 of water. This shows the temporary hardness.

The normal solution of hydrochloric acid for this test is made by taking 40 cubic centimeters of pure, concentrated hydrochloric acid, cooling it to 15 deg. C., and diluting it to 1000 c.c. by adding distilled water. This should be labeled "Standard Acid N5," and the strength can be kept by weighing out carefully 4 grams of the pure carbonate of soda which has been dried at dull red heat in a covered platinum dish. Dissolving this in a porcelain dish in a small quantity of water, adding a large volume of cold water and then testing with the acid solution from canary yellow to faint pink. If the acid solution is of the right strength, about 20 c.c. of the solution should be required to neutralize the sodium carbonate.

To test for acidity of water, a standard alkaline solution is used, and phenol-phthalein for a color indicator. This liquid is colorless with acids, and purplish red with alkalies, so that the standard alkali solution is dropped in, and stirred constantly until the permanent purple red color is obtained. The number of cubic centimeters of standard alkali solution used is the alkali equivalent of the acid strength in the water. The standard alkali solution is made by dissolving 21.5 grams of pure carbonate of soda in 250 c.c. of hot distilled water, the solution being then diluted to 1000 c.c. with cool distilled water, and cooled to 60 deg. F. This solution should be labeled "Standard Alkali N5." When testing the water for alkalinity, the number of cubic centimeters used of the standard acid solution is multiplied by 9.5 to give the parts per 100,000 of water. When testing for acidity the cubic centimeters of standard alkali solution used are multiplied by 9.58.

Tests for Oil

In plants where return water is used for feeding the boiler, one of the most important tests to be made is to ascertain whether or not any oil is present in the water, for its effect upon the boiler plate is liable to cause the boiler to bag and is believed to be the cause of many boiler explosions. To make this determination, about 250 c.c. of the water are put into a separating funnel which is provided with a stopper, and, after about 1/5 of its volume of ether or petrol have been added the contents is vigorously shaken and the funnel allowed to stand for a quarter of an hour, upright, and the water is then drawn off by the separating cock at the bottom. The ether or petrol solution which floats on the water, and which would take up all the oil in the water, is then run into a porcelain dish and evapor-

ated over a water bath. No flame should be allowed to come in contact with the fumes which are driven off by the heat of the water bath as they ignite readily and may cause serious results. The solution will evaporate rapidly, leaving only the oil which was in the water in the evaporating dish. It is not usual to determine the exact amount of the oil present in the feed-water as any amount will be undesirable, and provision to eliminate it should be made.

Sulphate of lime is a scale-forming ingredient found in some boiler feed-water which is responsible for the hardest kind of scale. In boilers it precipitates as heavy crystals when 50 lb. of steam pressure has been reached, and is more adhesive to boiler shells than the carbonate of lime. It is indicated by the formation of a white precipitate when a little chloride of barium is added to 1½ in. of water in the test tube. This precipitate will not re-dissolve when a little nitric acid is added, and is thus distinguished.

To test for the presence of magnesia, put water into a test tube to ⅓ its depth, and bring it to a boil. Then, adding a little carbonate of ammonia and a trifle of potassium of soda, magnesia, if present, will come down as a white precipitate but may take a little time to do it, so that the tube should be set aside for a few minutes to settle.

Any of the tests given above can be performed by an engineer who is not an expert chemist, but, in that case, could not, of course, be used as the basis on which to prescribe a treatment for eliminating the scale. The results, however, are valuable to show whether or not the water should receive treatment.

Boiler Room Economics

SELECTION OF FUEL BY MEANS OF TESTS, POINTS IN FURNACE DESIGN, FIRE BRICK. BY P. M. CHAMBERLAIN*

SECURING of fuel best adapted for the use of a plant is a phase of economic operation which is not always given due consideration. If the equipment is well adapted to, and a wide variety of fuel is available on reasonably equal freight charges, it gives opportunity to select with precision the most economical coal. If, on the other hand, there is a limited selection of coal available it is quite likely that the plant may need revision to meet the requirements of the particular coal available, so as to burn it with the greatest efficiency. In the case where a variety of fuels is available, careful tests should be run to determine the most advantageous offer.

The tests should be continuous, though not elaborate in detail and should take into account other factors than the coal, such for instances, as the fireman on duty, if in a small plant; or the system employed by the foreman, if in a large plant. The tests require no other data than should constitute a part of the continuous record of the plant.

One of the most surprising instances of inefficient methods is found in plants running without any definite knowledge of how much water is being evaporated for a dollar's worth of coal. This condition can be accounted for only on the basis of inertia of mind, a disinclination to enforce new methods or a haphazard satisfaction in guess work on the part of the management, based on the opinions of various employes.

The character of the plant and the duty imposed on it, will predetermine to a considerable extent, the character of coal which would be most advantageous and if that character of coal is not in competition or readily obtainable in the particular market, the plant should be revised to meet the character of coal which is available. It requires no tests or calculations to prove the desirability or economy of this step, other than simple observation and deductions from the performance of the plant.

If the equipment is prepared to burn, with reasonable efficiency, the coals which are available in the market, the reports of operation should enable the management to know how much water, from and at 212 deg., is evaporated per pound of coal as received, of each particular lot, together with the proximate analysis of the coal, its B.t.u. content and the general satisfactory operation, as regards meeting conditions of fluctuations of load, the effect on the tubes, grates and brickwork of the boiler setting and the comparative amount of labor in firing, cleaning and disposal of ashes. The frequent inspection of the ash heap may disclose an amount of unburned fuel, which, with different methods of firing, would have brought the coal showing a poor record into a more efficient investment.

BITUMINOUS COALS

COAL SHOULD be purchased on a basis of heat value, and the particular method employed must, of course, be adapted to the local conditions. This method of purchase has been gaining in favor, both with the user and seller for a number of years and has for its chief recommendation the fact that the consumer pays for what he gets. There have been specifications and contracts made under this general system, which were unsatisfactory but in such cases due entirely to the systems not having been fitted to the conditions, or a lack of proper enforcement.

The technical press and the state and government bulletins give excellent information regarding various systems which have been employed successfully. They may be classified broadly into 2 classes, one of which stipulates the definite heat value and percentage of carbon, volatile matter, moisture, ash and provides penalties or deductions for variations from these standards. If the market affords but a limited character of coal

*Graduating from the engineering courses of Michigan Agricultural College and Sibley College, Cornell University, Mr. Chamberlain spent 4 yr. designing and erecting power and refrigerating plants with the Frick Co. and Hercules Iron Works; then 12 yr. in teaching mechanical engineering, the last 9 at the head of the engineering work in Lewis Institute; following this, a year designing gas engines and 3 yr. as Chief Engineer for the Underfeed Stoker Co. of America; and for 3 yr. past has been in private consulting work on power-plant design and improvement.

this method may be satisfactory. Another method, which gives a much wider variation and aims to fix a basis of price which will enable the purchaser to select from various bids, is that which enables him to secure the largest number of units for a unit price, and if the equipment is flexible enough, this system is the more satisfactory.

Bituminous Coals

As regards the different characters of bituminous coal, the constituents may be discussed in a general way as follows: A coal high in carbon, low in volatile and ash, is a free-burning coal and will enable a plant having poor draft conditions and small grate areas to achieve the maximum output. It is also desirable to use such a coal if the furnace is deficient in height and the combustion space restricted. A coal high in volatile requires ample grate areas and combustion space to burn to the best advantage, otherwise the proper admixture of air will not have been effected, with consequent waste of heat in unconsumed gases. A coal high in ash may prove, at the price offered, to be the most economical, but in general the proportion of ash in a pound of coal is not only a measure of the amount of inert and dead matter, but it is an obstruction and detriment to the proper combustion of the remainder. It obstructs the flow of air through the grates, thereby necessitating larger grate area or higher draft; it surrounds particles of the coal, preventing the access of air, and may, under certain conditions of combustion, fuse with the grate bars, or be deposited on the brickwork and gas passages and generally reduce the efficiency of the actual combustible in coal.

Coal high in sulphur may or may not be undesirable, depending on the chemical combination of the sulphur with other elements. If the sulphur is in a free state, the effects are not harmful, but in certain combinations it fuses into a pasty mass making it impossible to get a proper supply of air. In other cases it makes a deposit on the brickwork in the form of projections and frequently fusing with brickwork in such a manner as to produce a flux causing the brickwork to run.

The exact action of sulphur cannot, with the present knowledge, be definitely foretold from the chemical analysis, so it is important, in the matter of purchase of coal, to avoid coal from a particular seam which has generally these undesirable characteristics, or, should this coal be particularly advantageous as to the number of heat units which can be bought for a unit price, it may be advisable to revise the equipment so that such coal can be burned satisfactorily.

Comparing Coals

In making a comparison of different coals to determine the most desirable kind to buy, the aim is to find how the largest number of heat units can be obtained in the steam, for a unit price. This unit price of course includes not only the cost of the coal but the maintenance and repairs on the grates, stokers, brickwork and boiler and the labor cost for firing, cleaning and removing ashes. Assuming, for example, that the different kinds of coal available represent the same desirability in all matters excepting the B.t.u. value, then the problem resolves itself to determining the largest number of heat units which can be bought for a unit price.

The records of the boiler room should cover the actual weight of coal burned, weight of ashes, pounds of water evaporated, temperature of feed-water and steam pressure, from which data the necessary calculations can be made. The method to be employed for weighing can be suited to the local conditions. If it is possible to keep the particular lot of coal, under investigation, separate from other coal, the weight as checked on the car may be sufficient, but a much more satisfactory way is to weigh the coal as it is received on the firing floor.

There are many excellent systems of automatic weighers but in the absence of such, the ordinary platform scale set at about the weight of a barrow of coal, will serve, the coal being wheeled over the scale and a small amount taken off or added on, to make the exact weight.

The matter of measuring water is rather more complicated and difficult. It is desirable to have the best measuring device obtainable, and in the long run, the expense is justified in any plant where close figuring is desired. In the order of accuracy, would come weighing tanks, measuring tanks, venturi meters and ordinary water meters. A rough approximation can be obtained from the strokes of the pump after having made a calibration by operating the pump under about the usual conditions of speed and resistance, and weighing the water for a given number of strokes.

Where the advisability of installing accurate and more expensive apparatus is not appreciated, an ordinary water meter can be employed, having the piping so connected that it is possible to calibrate the meter frequently with tanks of known capacity, thereby having a correction to apply to the meter readings from time to time. The heat transferred to the water is easily ascertained by multiplying the number of pounds of water by the total heat in a pound of steam at the observed pressure (as found in the steam tables) minus the difference in heat from 32 deg. up to the temperature of the feed.

Gas Analyses

The refinements involved in making analyses of the gases, while desirable, are practicable only when the engineer, or some person interested, follows the matter with much care. Gas analysis, either by the Orsat apparatus or by the CO_2 recorder, is of greatest value in determining how to run the fires with the particular coal, to secure the most perfect combustion. In a great many plants, however, the knowledge desired is not what might be possible with great care but actually how much heat can be obtained for a unit price, under the ordinary conditions of operation.

Furnace Design

The success attending the burning of any coal most efficiently depends on the following general factors: construction and design of furnace; disposition of heating surfaces and routes for the hot gases; air supply, which involves chimney conditions; care in firing and rate of combustion. In furnace design it is essential that the proper disposition of grate, heating surface and

brickwork shall be such as to allow the fuel to be burned with the minimum amount of air required for combustion.

Tile furnace roofs, deflecting arches, etc., are details which should be carefully worked out, when the requirements of the particular plant are known. The amount of air necessary depends on the character of coal to be used and is obtained either with natural draft, forced or induced draft. If the grate area is necessarily small, or if the coal offered presents considerable obstruction to the passage of air, a high draft is necessary.

Having given in any problem, a rate at which the coal must be burned to give the requisite power, the character of coal to be used, the type of grate or stoker, the type of boiler as regards the passage of gases, the limitations as regards breeching friction, the draft equipment may be designed to meet, positively, the requirements.

The selections of boilers, draft apparatus grates or stokers is a problem involving not only the requirements of the plant, but also the factors of first cost, depreciation and repairs, attendance and efficiency. The selection of proper brickwork for boiler settings is important, especially if high rates of combustion are necessary with consequent high temperatures.

Fire brick is composed of hard or flint clay and plastic clay, the basis being silica and alumina. Certain impurities are found, such as iron, lime, magnesia, alkalies, and titanic acid. Fire brick should be made up in proper proportion of hard flint clays to resist the heat and soft or plastic clays necessary for binder. It is important that a high grade of clay be used in laying up the brick as an inferior clay will melt, leaving open joints for slag to attach to, and in some cases the clay will form a flux and destroy the highest grade of fire brick.

The character of fire brick and clay which should be used depends on the design of the furnace and the temperature to which it is likely to be subjected. According to the U. S. Bureau of Standards, common fire brick of clay composed of kaolin, melts at from 2831 to 3137 deg. F.; bauxite brick, 2949 to 3245 deg.; silica, 3100 deg.; chromite, 3722 deg.; and magnesia, 4929 deg. F. High grade clay brick contracts slightly under heat and silica brick expands.

Where it is necessary to employ arches of considerable span, the safest procedure is to submit the proposition to manufacturers of brick who have been successful in meeting similar conditions, and have the work done by a mason who has had experience in this class of work.

Coal Analysis

VALUE AS A GUIDE IN MAKING CONTRACTS, USUAL DETERMINATIONS, METHOD OF ANALYSIS, HEAT VALUE. BY PHILIP A. MOORE*

THE number of power plants which buy their coal on analyses is rapidly increasing. The time when any black substance that was called coal could be sold to a steam plant has passed. The engineer now requires an analysis showing the grade of fuel which he intends to purchase. The following is taken from a bulletin issued by the United States Geological Survey:

"The people of this country have been purchasing coal for years on the statement of the selling agent as to its quality, or on the reputation of the mine or district from which it is obtained. The farmers of the country show more business judgment in the purchase of fertilizer than do many manufacturers in buying coal, for the farmer demands a chemical analysis of the fertilizer before he accepts it. When the bidder is allowed to specify the quality of coal he proposes to furnish, as determined by chemical analysis, he is placed on a strictly competitive basis with other bidders. Such a procedure broadens the field for both the bidder and the purchaser. It makes the bidder's proposal, when accepted, a contract that specifies an established standard of quality. This furnishes a basis for settling disputes regarding the quality of the coal delivered and the price to be paid, if the fuel is either better or poorer than has been guaranteed. If other coal must be substituted, as often happens, there is a standard for settlement. If the coal is uniformly poorer than the standard, there is a basis for cancellation of the contract.

"The aim in the purchase of coal for any power plant should be to obtain a fuel that will produce a horsepower for the least cost, all things being considered; such as the equipment, the price of coal, and the cost of labor and repairs. In general, it may be said that in any market the coal obtainable at the lowest price on the basis of its heating value is the most economical, provided the furnace equipment is suitable. If the furnace is not so designed as to permit the use of the cheaper coal, it should be changed. The results of the government tests show that, other conditions being equal, coals of similar composition are of value in proportion to the British thermal units in the coal as received—a basis on which, indeed, all coals may be valued approximately. It should be remembered, however, that the value of coal for any particular plant is influenced by the fact that all furnaces are not equally suitable for burning the many grades of coal. Aside from this factor, coal may be compared in terms of the British thermal units obtained for 1 per cent, or on the cost for a million heat units. In the purchase of coal, then, attention should be given to the character of the furnace equipment and the load; the character of coal best suited to the plant conditions; the number of heat units obtainable for a unit price; the cost of handling the coal and ash; and the possibility of burning the coal without smoke or other objectionable features."

Coal shipments vary in quality, even if from the same mine, so that an analysis should be made on each ship-

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ment. Should any shipment fall below the guaranteed value, the purchaser should pay less in proportion for the poorer grade; should the reverse be true, the dealer is entitled to a bonus. A coal contract should be fair to both parties; the limits on B.t.u., moisture, ash, and sulphur, should be clearly stated, together with the deductions or bonuses to be paid if the coal is below or above the contract grade. The most satisfactory contracts to all concerned are those that insure a uniform grade of coal to the consumer, without reductions or bonuses to the dealer.

Analysis at the Plant

A brief statement of the methods used in coal analysis should prove of benefit to the engineer by making the terms used in reporting coal analyses more familiar to him. An up-to-date power plant could install apparatus to make some of the analyses at small cost. If only moisture and ash were determined on a sample, and the B.t.u. determination made on the outside from time to time, much valuable data could be obtained. If the moisture, volatile matter, fixed carbon and ash are known, the B.t.u. can be obtained by comparing with similar analyses in the bulletins on coal issued by state and government surveys, in which the B.t.u. is given.

The most important part of the analysis of coal is the securing of a truly representative sample of the shipment. For power-plant work the following method will give satisfactory results when carefully done:

Ten or more cores are taken from different parts of the car or wagon by means of a sampling ram. This ram is made of a 5-ft. length of heavy 2-in. iron pipe, sharpened at one end, this end having a collar on the inside to prevent the core from dropping out when the ram is removed from the coal. The other end of the ram is reinforced so that it may be driven into the coal with a maul. The 10 cores are put in an air-tight container and sent to the laboratory. If the laboratory is at some distance, the sample may be crushed with a hammer to about ½ in., then cut and quartered, mixing well each time until about a quart of sample remains. This sample is then put in a quart Mason jar and sent to the laboratory.

Moisture as Received

When a sample is received at the laboratory it is crushed to pea size and quartered down to about one pound. Four ounces are taken from the sample for the determination of total moisture or "moisture as received." The remainder is pulverized to 20 mesh. A 10-gram sample is removed from the 4-oz. sample of pea-sized coal and the moisture "as received" determined as follows: The 10-gram sample is put in an oven fitted with thermometer and heated for 1 hr. at a temperature of 221 to 225 deg. F. At the end of the hour the sample is removed from the oven, placed in a dry atmosphere till cool, and then weighed. The loss in weight gives the total moisture present in the coal.

The sample which has been reduced to 20 mesh (if damp, it should be dried, as damp coal is hard to pulverize) is well mixed and several small spoons of coal are selected at random from the pile; this small sample of 10 to 20 grams is then ground so that all of it will pass a 100-mesh sieve. The sample which has passed the 100-mesh sieve is then put into a test tube and closed with a rubber stopper. The remainder of the 20-mesh sample is put into a tight glass jar and kept on file for check analyses, should they be required.

The 100-mesh sample is used for the proximate analysis and the B.t.u. determination. The proximate analysis determines the ash, moisture, volatile matter, fixed carbon and sulphur. The following procedure is the one generally used:

Proximate Analysis

Moisture in a coal is considered to be all of the water that can be driven off by heating the coal for an hour at 221 to 225 deg. F. A 10-gram platinum or porcelain crucible with lid is weighed on a fine chemical balance, a 1-gram weight is then added to the weight side of the balance and enough 100-mesh coal added to the crucible to counterbalance the added weight. The crucible containing the 100-mesh sample is put in an oven and heated for 1 hr. at 221 to 225 deg. F. The crucible is removed from the oven, cooled in a dry atmosphere and weighed. The loss in weight gives the amount of moisture in the 100-mesh sample; this moisture is generally lower than the total or "moisture as received."

The ash is determined by burning all of the combustible matter in the dried sample from the moisture determination. The lid is removed from the crucible containing the dried coal and a small Bunsen burner flame is put under the crucible until all volatile matter has been driven off; the heat is then increased till all of the carbon has been burned. The crucible is allowed to cool and then weighed. The weight of the crucible alone, subtracted from the crucible, plus ash, gives the weight of ash in the coal.

The volatile matter or gaseous substances that are given off by heating the coal, is determined by weighing a fresh gram portion of the 100-mesh coal into a crucible with a tight-fitting lid. The crucible is placed on a triangle and heated for 7 min. with an 8-in. Bunsen burner flame, the crucible about 3 in. above the top of the burner. After ignition the crucible is cooled and weighed; the loss in weight, minus the moisture previously found in the 100-mesh sample, gives the volatile matter. The fixed carbon is obtained by adding the percentages, moisture, ash, and volatile matter together and substracting the sum from 100 per cent. For example, the crucible weighs 10.2510 grams + 1 gram coal = 11.2510 grams. Weight, after drying crucible and coal for one hour, is 11.2010. 11.2510 — 11.2010 = 0.0500 grams, or 5 per cent as the percentage of moisture.

Sulphur Determination

Ash and moisture cut down on the B.t.u. value of the coal, while the volatile matter, fixed carbon, and sulphur all raise the heating value. The determination of sulphur in a coal is rather complicated; the principle is as follows: A gram sample of the 100-mesh coal is burned with a mixture which absorbs all of the sulphur, this mixture is then analyzed for sulphur. Sulphur need not be determined in most cases and is not important unless the amount runs so high as to cause trouble from clinkers. Coal high in sulphur is apt to clinker badly.

Heat Values

The heating values of coal are determined in British thermal units or calories; the first is the common notation in engineering practice. A B.t.u. may be defined as the quantity of heat necessary to heat one pound of water 1 deg. F. and the B.t.u. value of a coal, the number of these heat units contained in 1 lb. of coal. Although the B.t.u. value may be calculated from an analysis with fair accuracy, a separate determination is usually made in an instrument called a calorimeter. A calorimeter measures the quantity of heat given off when a small sample of coal is burned. Knowing the heat given off when, say, 1 gram of coal is burned, the heat given off by burning 1 lb. can be calculated.

There are 2 general forms of calorimeter in use—the oxygen bomb and the sodium peroxide. In the oxygen bomb calorimeter the coal is burned with oxygen gas under pressure, while the sodium peroxide instrument uses a solid chemical to furnish the oxygen necessary for combustion. The container, in which the oxygen or sodium peroxide, together with the coal, is placed, is surrounded by a weighed quantity of water in which is placed a delicate thermometer. Insulated wires lead to the combustion cylinder, so that the coal can be ignited by an electric current, which heats a fine wire inside the cylinder. The metal cylinder containing the coal and oxygen is placed in the water, the electric leads adjusted, and the water around the combustion cylinder is stirred until a uniform temperature is reached. A thermometer reading is then taken. The coal is fired by means of an electric current and another reading taken when a maximum rise in the thermometer has been reached. Corrections for radiation and other factors are made to the observed differences in temperature before and after firing the coal. The B.t.u.'s of the coal can then be calculated. The sodium peroxide calorimeter gives good results for most work and a large number of these instruments are in use throughout the country in large power plants.

A few words about the expressing of the B.t.u. value of coal is not out of place. The B.t.u. value of the coal should be calculated on the basis of coal "as received," this being the condition of the coal as it is burned under the boiler. If the coal be dried before reaching the laboratory, or the B.t.u. calculated for dry coal, a much higher heating value will be given than is actually contained in the coal. Say the coal "as received" and burned analyses:

B.t.u.	Moisture	Volatile	Fixed Carbon	Ash
11,276	5.00%	36.00%	47.00%	12.00%

On a dried sample this would be changed to:

B.t.u.	Moisture	Volatile	Fixed Carbon	Ash
11,868	0.00	37.89	49.47	12.64

so that for general work the report should be made on coal as received and not coal on a dry basis. The "dry basis" is useful in comparing different coals and, as the coal shows, a much higher heating value is often used by the dealer in giving reports on his coal.

From the foregoing discussion it is hoped that the operating engineer may get a clearer insight into the meaning and technique of coal analysis and that he may be able to form a better idea of the meaning of the different terms that are used in reporting such analyses.

Pyrometers

Temperature of Boiler Furnace and Stack Beyond Range of Ordinary Thermometers

In power-plant testing, a reliable and practical means is required for measuring intense heat, such as the temperatures of the gases at various points of the furnace, boiler and flues. Ordinarily, mercurial thermometers are most convenient for measuring temperatures up to about 400 deg. F., but temperatures in excess of this can best be determined by some form of pyrometer.

Several principles are employed in the design of pyrometers, the following types being commonly used: Thermo-electric, radiation, expansion or mechanical and mercurial.

Thermo-electric pyrometers depend for their action upon the fact that when 2 wires of different metals are joined at both ends so as to form a complete metallic circuit, and heat is applied at one junction, the other junction being kept at a lower temperature, an electromotive force proportional to the difference of temperature is generated, which can be measured with a galvanometer. The 2 wires, or elements, thus used form the thermo-couple, and may be joined by a pair of flexible leads to the galvanometer or meter, which indicates the temperature in deg. F. or C. Thermo-couples are of the high and low-resistance types, and are known as rare metal and base metal couples, respectively. The former is composed of 2 wires, about 0.02 in. in diameter, one being of platinum and the other of an alloy of platinum and rhodium; while in the latter type the elements, which are about ⅛ in. in diameter, are usually made of alloys of nickel, iron and copper. Base-metal couples are of rugged construction and can be used for temperatures up to 1800 deg. F. or higher, while the rare-metal type is adapted to temperatures as high as 3000 deg. F., but requires somewhat greater care in handling.

Radiation pyrometers depend upon the measurement of heat radiated from the hot body, the rays being reflected by a concave mirror or lenses upon a thermo-couple located at the focus. As no part of the apparatus is subjected to the actual temperature to be measured, it is possible to determine temperatures up to 3600 deg. F., which are beyond the range of other types of pyrometers.

Mechanical pyrometers consist essentially of 2 metal rods having different rates of expansion, iron and brass

cold end, changes in temperature cause expansion and contraction of the mercury, having the effect of changing or graphite and iron being commonly used. The movement is transmitted by means of gears and levers to a pointer which moves over a graduated scale. Temperatures up to about 1000 deg. F. can be measured in this manner.

For temperatures below 1000 deg. F., the mercurial pyrometer is well adapted. It differs little in construction from the ordinary thermometer except that it is made of special glass and the space above the mercury is filled with nitrogen under pressure, which prevents vaporization and boiling of the mercury. In addition, it is necessary that the instrument be properly protected from mechanical injury by a metal tube and case.

Besides the above may be mentioned the water pyrometer, which depends upon the rise in temperature of a known quantity of water flowing through a portion of the apparatus placed at the source of heat.

Calibration of pyrometers is accomplished by the use of fusible alloys whose melting points are known, the pyrometer element and alloys being heated until the fusing points of the latter are reached. Another method is by comparison with a special standard electric resistance thermometer. For the low ranges, calibration is easily made by comparison with a mercurial thermometer or pyrometer of known accuracy.

Bristol Pyrometer

BRISTOL CO., WATERBURY, CONN.

IN the construction of this pyrometer, 2 patented types of thermo-couples are used, one in which the elements are made of base metals, or low-priced, special alloys, and the other a combination of rare metal and inexpensive alloys, low resistance elements. These pyrometers with the base metal couples were, from the first, designed

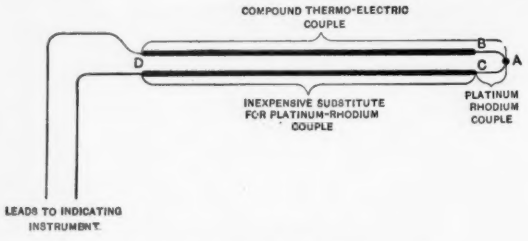

FIG. 1. DIAGRAM ILLUSTRATING COMPOUND THERMO-COUPLE

to be practical for use under ordinary shop conditions.

Base metal thermo-couples are composed of 2 wires or elements welded together at one end, and are of large cross-section so that they have the advantage of low resistance and strength. This type of fire end, although intended for use at ordinary temperatures, has been found to be quite durable at high temperatures.

In Fig. 1 is shown a compound couple, designed to produce an inexpensive equivalent of the platinum-rhodium couple, which is necessary for use in certain high temperature measurements. The platinum-rhodium elements extend from the junction A to the thermo-electric junctions B and C, but from B and C to D the couple consists of low-priced alloys, effecting a great saving in rare metals, as only the active part of the couple is made of platinum-rhodium. The alloys employed in this construction are such that the electromotive forces generated are equal and opposed, the resultant electromotive force being the same as if the couple throughout its entire length were made of the platinum-rhodium element.

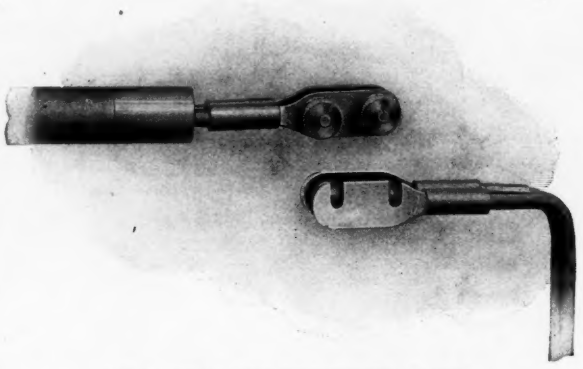

FIG. 2. SEPARABLE CONNECTION OF FIRE END AND COLD END EXTENSION-PIECE

The base metal couple is adapted for continuous service at temperatures up to 2000 deg. F., also intermittently for temperatures higher than 2000 deg. F. Where temperatures as high as 3000 deg. F. are encountered, the compound thermo-couple and portable pyrometer outfits for quick readings and intermittent service may be used with reliability.

Owing to the fact that it is necessary to keep the cold end of the couple away from the source of heat, maintaining it at a constant temperature, and that the part of the couple subjected to the high temperature may occasionally need replacing, a patented cold end extension piece is joined to the thermo-couple proper. The connections, Fig. 2, between the fire end and extension piece are specially slotted and fitted with binding posts so as to avoid joining the fire end and extension piece with reverse polarity.

In calibrating Bristol pyrometers, it is usually assumed that the cold-end temperature will average 75 deg. F., but where there is any considerable variation from this, the difference between 75 deg. and the actual cold-end temperature should be added to or subtracted from the reading indicated by the instrument, depending upon whether the cold-end temperature is greater or less than the normal temperature.

In most cases the separable couple with the cold-end extension piece takes care of the cold-end temperature, but in such cases, where the cold-end temperature cannot be conveniently controlled or correction easily made, a patented automatic compensator is used, which consists of a glass bulb of mercury, through which passes a short length of fine platinum resistance wire. As the compensator is connected in series in the circuit near the

the resistance offered by this length of platinum wire, since the rise and fall of the mercury short circuits more or less of the resistance wire.

For general tests and for measuring temperatures intermittently at a large number of different places, the portable form of indicating pyrometer is found very convenient. Where permanent records are desired, a recording instrument is used, of which there are 2 types, the ink type and the smoke-chart type. Both instruments are exactly the same except for the method of recording. The ink type produces records consisting of a red line traced on a white printed chart, while the smoke-chart type traces off a line on a brown surface, through which the graduations of the chart can be easily seen. The brown coating on the surface of the chart is made very sensitive, and in order to preserve the record after removal, one has simply to dip the surface of the chart in a solution of fixative, which renders the record ineffaceable.

By means of a vibrating device, operated by a clock movement, the chart is brought into contact with the tip of the recording arm at regular intervals of about 10 sec., after which the chart is quickly carried back, leaving the recording arm free and clear of the chart. The Weston Electrical movement is mounted on hinges at the back of the case, and in order to change charts it is only necessary to swing the movement around, leaving the chart entirely unobstructed. Except for the momentary contact of recording arm and chart, the arm is unhindered, thus eliminating friction.

Brown Expansion Pyrometer

BROWN INSTRUMENT CO., PHILADELPHIA, PA.

OPERATION of this instrument is based on the principle of expansion, the instrument having an outer steel stem and graphite rods inside, extending for 12 in., the difference in expansion between the graphite rods and the steel stem causing the pointer to

BROWN PORTABLE INDICATING PYROMETER

indicate the degrees of temperature on the dial. The instrument is designed for an exposure in the heating region of 12 in. or more of the stem, which is usually 36 in. long, and is compensated so that it will show exactly the same temperature, no matter how much the stem or tube above 12 in. may be inserted in the heat.

Temperatures up to 2000 deg. F. can be indicated by such an instrument, and it is designed to withstand rough usage. The dial is of enameled iron, and cannot break or tarnish, although subjected to high temperatures.

For measuring temperatures up to 1000 deg. F., the mercurial pyrometer may be used, which is similar to a low-temperature thermometer, with the exception that the high-range instrument is filled with a hydrogen gas above the mercury to prevent boiling.

Where a continuous record of the temperature is desired, a recording instrument, based on the expansion principle, can be supplied, as above described. Instead of the indicating instrument with dial, a recording case with chart is furnished.

Hoskins Pyrometer

HOSKINS MFG. CO., DETROIT, MICH.

PYROMETERS made by this company are the thermo-electric type, having 2 essential parts, Fig. 1, the thermo-couple and the meter. The thermo-couple, which generates the electric current, is composed of 2 wires of dissimilar metals twisted and welded at the hot end. Except at the hot end, the 2 wires, or elements, do not touch, and, beginning at a point just back of the twist, each is wrapped with an asbestos winding, which serves as an insulation, both

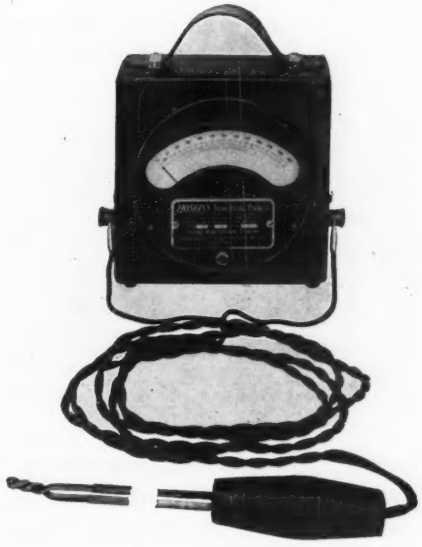

FIG. 1. HOSKINS PORTABLE PYROMETER, SHOWING METER, FLEXIBLE LEADS AND THERMO-COUPLE

electrically and thermally. The free or cold ends of the couple are enclosed in a 2-piece handle, Fig. 2, which serves as a container for a composition spool on which the calibrated resistance is wound and in which thermo-couple terminals are mounted.

When the hot end is placed in the furnace, or at the source of heat where the temperature is to be measured,

the heat generates an electromotive force whose intensity is determined by the difference in temperature between the hot and cold ends. The temperature of the latter generally agrees with that of the air.

Elements of the standard Hoskins thermo-couples are ⅛ in. square in section and approximately 3 ft. long; although other sizes are used. The couples are made of special alloys—inexpensive, but thoroughly dependable and durable, and when cold are flexible enough to be bent

FIG. 2. THERMO-COUPLE HANDLE OPEN, EXPOSING TERMINALS, CALIBRATING RESISTANCE AND LEAD - ADJUSTING RESISTANCE

in any desired shape. Protecting tubes are used to insure the couples against mechanical injury and to protect them from the action of high temperatures and gases.

The meter used, which is connected to the cold end of the thermo-couple by a pair of flexible copper wire leads, is of the D'Arsonval type, and indicates directly the temperature in degrees Fahrenheit or Centigrade. The high electromotive force generated by this couple permits the use of a modified form of a D'Arsonval double-pivot meter, Fig. 3, a type that is both rugged and accurate. Resilient jewel mountings protect the jewels and pivots under severe conditions of use.

Both couple and meter have a low temperature coefficient, which eliminates a common source of error.

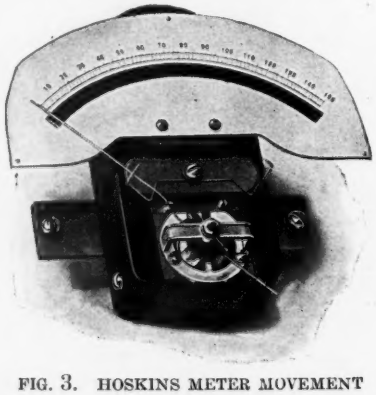

FIG. 3. HOSKINS METER MOVEMENT

Adjustment is provided to eliminate the so-called cold-end error, which is equal, approximately, to the difference between 77 deg. F. and the actual temperature of the cold end. With the zero adjuster it is necessary only to reset, by means of the thumb screw, located just below the name plate, the zero or starting point of the meter to agree with the temperature of the thermo-couple, whereupon the meter will automatically indicate the true temperature of the hot end.

The meter is graduated into 25-deg. divisions and can be used with accuracy over a wide range between 200 deg. and 2500 deg. F. The standard equipment of leads is 20 ft. in length.

One meter may be used to indicate the temperature at several points where thermo-couples are installed (such as a battery of furnaces) by running leads from each couple to a central selective switch connected with the meter.

The Hoskins recording pyrometer, Fig. 4, has practically the same meter movement as the indicating instrument. The record is a series of dots, made on the back of the translucent chart, and, from the front of the chart, appears to be a continuous line.

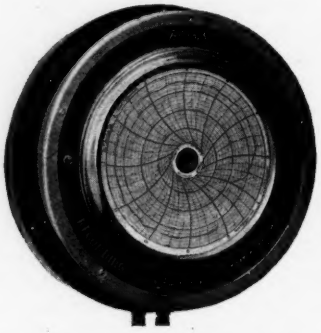

FIG. 4. HOSKINS RECORDING PYROMETER

The dots are made at half-minute intervals by a metal stylus carried on the end of the pointer, being pressed momentarily against a sheet of inked carbon behind the chart. The stylus is operated by a cam-driven striking arm. The glass front of the meter serves as a platen, by means of which duplicate records can be made.

These pyrometers, while possessing a high degree of accuracy, are built to withstand the hard-service conditions of the average boiler or heat-treating room.

Foxboro Pyrometers

INDUSTRIAL INSTRUMENT CO., FOXBORO, MASS.

FOR making boiler tests the low-resistance indicating pyrometer of the portable form is convenient and effective. For temperatures up to 1800 deg. F., the base metal bars, Fig. 1, are used with a special millivolt meter. These base metal couples are interchangeable and any instrument may be calibrated for use with these fire bars for any range up to 1800 deg. F. Only the temperature at the end of the bar affects the readings, and bars may be bent cold to a 1½-in. radius without injury if not hammered. Any number of fire bars of the same or different lengths may be connected to one indicator through a simple switch arrangement.

Instead of 2 wires in these bars, there is one bar and one tube, Fig. 2, the installation K being inside between the bar and the tube, where it is away from wear and tear.

When using the fire bar portably for intermittent readings, no protection pipe is required, but when the fire bars are subjected to continuous heat above 800 deg. F., they should be protected by an iron pipe welded closed at one end.

On the high-resistance type for any range up to 3000 deg. F., the Le Chatelier type of galvanometer, made with a single pivot at the center of gravity, is used with a platinum-rhodium couple. Quartz pyrometer tubes are

FIG. 1. BASE METAL FIRE BAR ATTACHED TO LEADS

recommended and should be used for protecting platinum couples for portable work, even for temperatures as high as 2600 deg. F. For installations where the couple

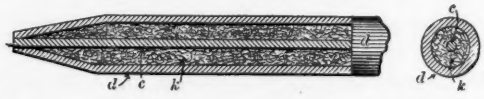

FIG. 2. SECTIONS THROUGH FIRE BAR, SHOWING ITS CONSTRUCTION

can be allowed to heat and cool slowly with the furnace, Marquardt-masse outer tubes with double-bore fire clay inner tubes will give very satisfactory results.

Schaeffer & Budenberg Pyrometers

SCHAEFFER AND BUDENBERG MFG. CO., BROOKLYN, N. Y.

BOTH the base metal and platinum-rhodium thermo-couples are used in pyrometers made by this company.

The base metal thermo-couple, Fig. 1, is usually formed of 2 wires or rods ⅛ in. in diameter of a nickel alloy twisted and welded together at the lower end. Asbestos for ordinary temperatures and indestructible lava for high temperatures are used as insulation. A protecting sheath with adjustable flange, and a head of steel and porcelain with binding posts make the complete couple.

The platinum-rhodium couples are formed of one wire of chemically pure platinum, and the other of platinum and 10 per cent rhodium, the diameter being 0.02 in. and the melting point about 3150 deg. F. The insulation, Fig. 2, consists of small fire-clay tubes pierced with 2 holes through which the wires run. Protecting tubes are made of either quartz or imported Marquardt porcelain.

For instantly indicating high temperatures up to 2400 deg. F., the portable electric pyrometer may be used, with a base metal thermo-couple. The thermo-couple is usually provided with a protecting cap, which is removed for measuring very high temperatures, or it

FIG. 1. S. & B. BASE METAL THERMO-COUPLE WITHOUT PROTECTING TUBE
FIG. 2. S. & B. PLATINUM-RHODIUM COUPLE, SHOWING INSULATING FIRE CLAY TUBES
FIG. 3. COLUMBIA PORTABLE RECORDING PYROMETER, SHOWING MOUNTING OF CLOCK AND CHART ON A REMOVABLE DRAWER
FIG. 4. S. & B. MERCURIAL PYROMETER

can be used with the cap for permanent installation at temperatures up to 1800 deg. F. For temperatures up to 3000 deg. F., a platinum-rhodium couple is used.

Construction of the "Columbia" portable recording pyrometer is such that the instrument may be placed on a bench or table with the chart in a horizontal position. The chart record consists of a series of dots, made by

momentary contact of the pen, which carries a small quantity of ink. The clock mechanism is carried on a removable drawer supported by guides, so that as the drawer is pulled out, Fig. 3, the chart drops away from the pen, thus enabling the chart to be changed with the pen arm entirely out of the way.

For measuring temperatures, such as that of flue gases, a mercurial pyrometer is found very accurate and convenient. The straight pattern, shown in Fig. 4, is graduated from 200 deg. to 1000 deg. F.

Fery Radiation Pyrometer

TAYLOR INSTRUMENT COMPANIES, ROCHESTER, N. Y.

TO measure temperatures with this instrument it is not necessary to insert any part of it in the furnace, and no portion of it is heated to more than 180 deg. F. above the temperature of the surrounding air. A complete temperature observation requires about 2 min., but quicker readings may be obtained by holding telescope in hand. The portable outfit includes a tripod on which the telescope may be set.

Following is the principle of operation: All bodies radiate heat. Heat rays may be reflected and focused as

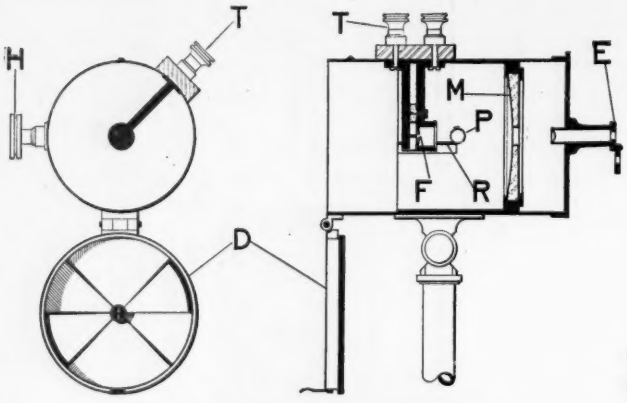

FIG. 1. ELEVATION AND SECTION OF FERY RADIATION PYROMETER

is light, producing, at the focus of a concave mirror, a heat image similar to a light image. In order to measure their intensity, the heat rays are focused on the hot end of a thermo-couple.

In Fig. 1 the heat rays strike the mirror, M, and are focused at F, the hot end of the thermo-couple. The cold end is screened from the focused rays and as both the hot and cold ends are subjected to the same surrounding temperature, there is no cold-end error. To guide the pointing of the telescope, an eye-piece, E, is provided at the rear end of the telescope, through which a reflected image of the hot body can be seen. The image of the hot end of the couple appears as a black spot and must be overlapped by the image of the hot body. The intensity of heat at the focus is unaffected by the distance of the instrument from the source of heat, but this distance should not exceed 30 times the diameter of the hot body.

Standard instruments are furnished with the following pairs of scale ranges: 1000 to 2400 deg. F. and from 1800 to 3600 deg. F.; 600 to 1800 deg. F. and 1100 to 2700 deg. F., or their centigrade equivalent. Indicating outfits are provided with an indicator connected to the telescope by flexible cable, and read direct in temperature. When the limit of the lower scale is reached, diaphragm, D, is swung over the mouth of the telescope and the temperature is read from a second scale.

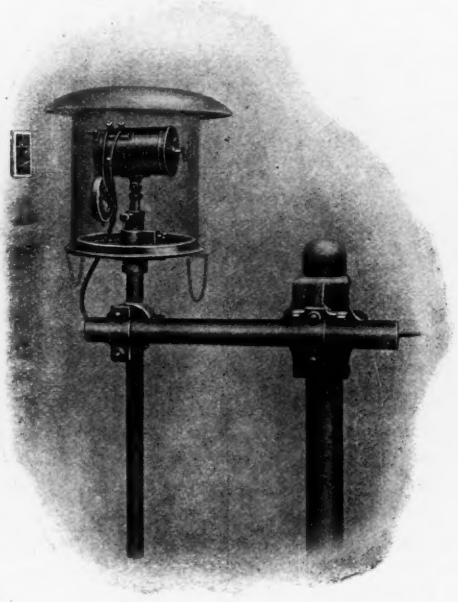

FIG. 2. FERY RADIATION PYROMETER IN WEATHER-HOOD SIGHTED INTO FIRECLAY TUBE

No accurate leveling is necessary, and with ordinary care in sighting and reading, the instrument should be accurate to within 1 per cent at the middle of the range and over.

In case it is not convenient to have a hole in the wall of the furnace, the telescope may be sighted into a closed end fireclay tube projecting well into the furnace, Fig. 2. With a recording outfit, a continuous record of temperature may be made. The recorder may be located at any required distance from the furnace.

CITIZENS OF Pittsburg, Tex., are fostering a movement to organize a stock company for the erection of an electric light and ice plant there. More than $15,000 has been subscribed to this project by the local business men.

GRANVILLE, N. Y., IS RECEIVING its electrical energy from the Kanes Falls Electric Co., whose power station is at Kanes Falls, in the town of Fort Ann. The power house at Kanes Falls has been rebuilt. The station of the Granville Gas and Electric Co., in Granville, has been changed and new machinery installed. New electric generators have been placed at the Kanes Falls plant, and last, but not least, a high tension transmission line, which is carried on steel poles, has been built across country from Kanes Falls to Granville, 15 miles.

Tycos Thermo-Electric Pyrometers

TAYLOR INSTRUMENT COMPANIES, ROCHESTER, N. Y.

PLATINUM, platinum-rhodium elements comprise the thermo-couples of rare metal thermo-electric pyrometers, and while the general principle used in the Le Chatelier type has been adhered to closely, the form of indicating and recording instruments has been

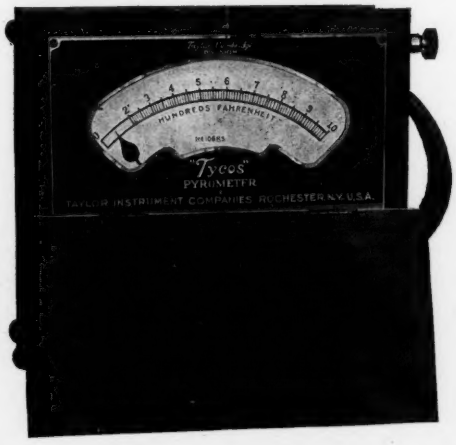

FIG. 1. TYCOS PORTABLE INDICATING INSTRUMENT

greatly improved. The types now made are designed for heavy duty and are simple and reliable. The thermo-couples are suitable for use at temperatures up to 3000 deg. F. in an oxidizing atmosphere, the melting point of the component wires being well above 3000 deg. F.

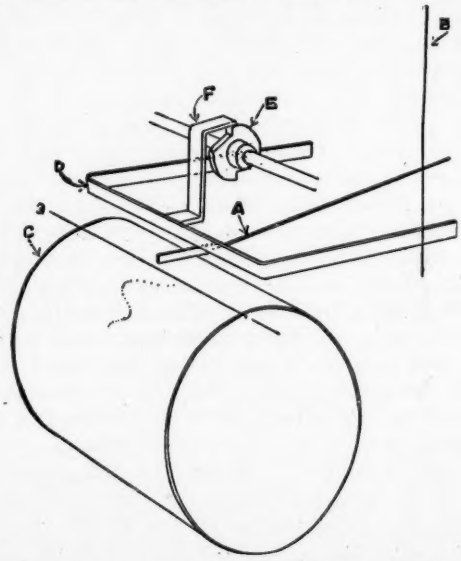

FIG. 2. DIAGRAM OF THREAD RECORDER MECHANISM

Attachment of the cable to the head of the thermo-couple is made by a nonreversible attachment plug, which has proven convenient and satisfactory in practical work. As the principle of measuring temperatures with thermo-couples is differential, the actual electromotive force measured by the indicator or recorder is the difference between that of the hot junction in the furnace and the cold junction, where the elements join the rest of the circuit. For accurate work it is important to keep the cold end at or near a constant known temperature. For high temperatures under industrial conditions, it is usually sufficient if the cold junction is kept fairly cool in the air outside the furnace, water jackets being supplied, if desired, for this purpose. These instruments are calibrated on the assumption that the cold-end temperature will be 77 deg. F., the indicator pointing at this temperature when disconnected from the circuit. If a different temperature exists, the pointer may easily be set accordingly, by the convenient external adjuster provided.

Indicators used with this instrument are sensitive millivolt meters of the moving-coil, permanent-magnet type, the movement being double pivoted and so constructed that no accurate leveling is required; the pivot and jewels are frictionless and are protected from injury in use by special design. The moving parts are light and withstand considerable rough handling, Fig. 1.

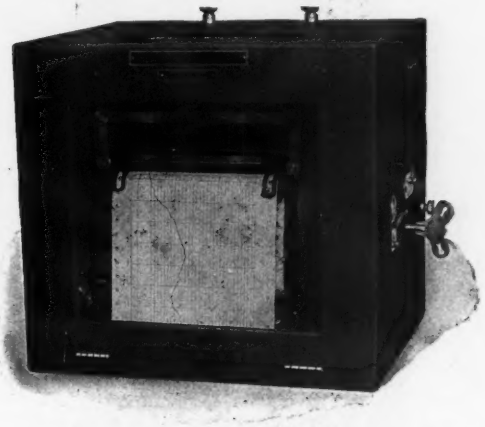

FIG. 3. TYCOS BASE METAL THREAD RECORDER

Figure 2 shows a diagram of the mechanism of the thread recorder. By means of the cam, E, and its follower, F, the pressure bar, D, above the pointer, A, is held normally out of contact with the pointer, thus avoiding friction, but at regular intervals the cam, E, makes half revolutions, allowing the pressure bar, D, to fall on the pointer, A, and then raising it again to its normal height. As the pressure bar falls, it depresses the pointer on to the drum, C, an inked thread, G, being between the pointer and the drum. The under side of the pointer is thin, hence a dot is made upon the drum, thus producing a visible record of the instantaneous deflections of the pointer. Actual temperatures can be read at any moment on the inspection scale fixed to the face of the presser bar.

With ordinary care, the accuracy of the outfit should be within about 1 per cent. The arrangement of the mechanism of the recorder is such that it can be withdrawn from its case for the purpose of examination or adjustment. Also maximum and minimum alarms may be fitted to the recorder and arranged to ring a bell.

The thread recorder is provided with a simple attachment for producing 2 simultaneous records on the same chart. Each record is in its distinctive color, hence where 2 temperatures are close together there is no confusion, the identity of each being plain. This makes a single instrument serve the purpose of 2, at slight additional cost.

Base Metal Pyrometer

Base metal thermo-electric pyrometers are employed where the range of temperature does not exceed 1800 deg. F. Their operation is similar to that of the Le Chatelier, or rare metal pyrometer, excepting that the thermo elements, instead of being platinum and rare alloys, consist of "base metals," such as nickel, copper, iron, etc.

FIG. 4. MULTIPLE INDICATING STATION FOR 20 POINTS

When used within the prescribed limits of temperature, base metal pyrometers compare favorably with the rare-metal type. The stems are more rugged and they do not require as careful handling.

Figure 3 shows the Tycos base metal recording pyrometer, which, when used in connection with the thermo-couple, gives a continuous automatic record of temperature. In this instrument, as in the thread recorder, the record is made by a succession of dots produced on the chart by the pointer, which is depressed periodically and intercepts an inked thread between it and the surface of the chart. As the thread is at right angles to the direction of motion of the paper, the charts have rectangular co-ordinates. The operation being similar to that of the typewriter, permanent ink records are easily obtained. The thread recorder is frictionless in its operation, is provided with 50-day chart and the only attention required is daily winding. The thread being impregnated by a special process, requires no inking and renewal about once yearly.

Single or multiple indicating outfits can be used for portable work or permanent installations. The multiple pyrometer shown in Fig. 4 is provided with switch for 20 points, so that observations of temperature at 20 remote stations can be measured at a central point. The convenience of this operation can be easily appreciated.

With the first mile of completed pipe in place, the officials of the Utah Power & Light Co. report rapid progress on the new wood stave pipe lines under construction near Grace, Idaho, along Bear River, as a portion of the extensive development work the company is doing at Grace and vicinity for generating increased electrical energy for its Utah and Idaho territory. Stretching straight and true for 23,000 ft. across the country intervening between the beginning of a big bend in Bear River and the new power house, the big pipe forms one of the most interesting and spectacular features of the company's work at Grace.

The pipe is 11 ft. in diameter from the point where it leaves the dam in the river until it reaches the top of the steep hill above the power house at Grace. Carefully prepared and matched lumber about 4 by 6 is used and 70 pieces laid side by side on circular forms comprise a complete circle and form a section of the pipe. They are belted with iron hoops and the entire pipe, from dam to power house, rests on concrete "saddles." These consist of heavy concrete base resting on bed rock, or sunk at least 4 ft. in the ground and a half circle of concrete, into which the pipe fits snugly. The saddles are 8 ft. apart throughout the entire length of the big tube and they form a permanent and safe anchorage for the pipe with its enormous load of water.

The water from the river enters the pipe at the dam and is carried with tremendous power and velocity down grade through the tubing to the top of the hill above the power plant. Here the pipe joins 2500 ft. of 8-ft. diameter steel pressure piping through which the water rushes to the turbines of the plant, furnishing the power by which the electrical energy is generated. This pipe is called a "penstock." The pipe is of the strongest steel and is received by the company in sections 22 ft. long, each weighing 8 tons. Over 8000 cu. ft. of excavating was necessary in trenching for this pressure drain pipe and the pipe is anchored every few hundred feet by concrete anchorages. The construction of the main pipe, and of the steel pressure pipe, has proven one of the biggest tasks confronting the Utah Power & Light Co. in its development of electric power along Bear River.

Whoever does the work that comes to his hand with all his strength of mind and body, singing at his work and making a song out of it, working ever for the great joy of working well—let us note him, for he is of the great ones of the earth; let us copy him if we can, for there is no happiness in life better worth the winning than this happiness in working well.—Steam Machinery.

Oil Analysis

VALUE OF AN OIL ANALYSIS, HOW IT CAN BE MADE, OILS FOR SPECIAL PURPOSES. BY PHILIP A. MOORE.

OF all the supplies used in the power plant, oil is the least understood by the purchasing agent and operating engineer; there are little or no data available on the subject, and if the oil gives fair satisfaction the matter is dropped. The mineral lubricating oils are often sold more by appearance, and the talk of the agent, than by their money and lubricating values.

To illustrate the point—a company has been buying a steam cylinder oil known as "Ruby Red Cylinder Oil." This oil has been used for some time and gives satisfactory service, although the price is high; the oil selling for 75 cents a gallon. On testing another oil, which is known as "Steam Refined Stock," selling at 25 cents a gallon, it is found to compare favorably in body or viscosity, flash and fire and perhaps in gravity with the higher-priced oil. In most cases the cheaper oil will be found to give just as satisfactory results as the higher-priced oil with the fancy name.

QUALITY AND PRICE

BY COMPARING samples of oil and furnishing specifications to several oil companies, the price of lubricants can often be successfully lowered. The fact that an oil is sold for a high price does not by any means signifiy that its quality is better than others; rather, that the field from which it comes is failing and the supply is not great enough for the demand. Such is the case with some of the Pennsylvania oils which are sold by reputation only. Mineral lubricating oils are produced by the distillation of crude petroleum. The gasoline and burning oils are the first products obtained from the crude oil, the lubricating oils remaining in the still after the lighter oils have been volatilized. The light, neutral oils, engine oils and steam cylinder stocks are separated from the remaining oil in the still by frictional distillation. The heavy-bodied cylinder stocks are the best to volatilize, and so have a high flash and fire point; the lighter engine oils which volatilized at a lower temperature, have less body and a lower flash and fire point.

VALUE OF OIL TESTS

TESTS MADE on lubricating oils are so easy and the apparatus so cheap, that no large user of oil should be without them. The viscosity or body of the oil is the most important factor, as this measures the degree of fluidity of the oil, or the internal friction; and within certain limits the viscosity is a direct measure of the lubricating value of the oil. The flash and fire points are useful in selecting an oil and serve as a check in testing oils that are furnished on specification. A low flash oil is unsafe to use on account of the fire risk and the oil may be volatilized to such an extent that little oil is left for lubrication.

Specific gravity or degree Baume of an oil serves to classify oils to some extent, the lubricating oils of a high Baume coming from the Pennsylvania or eastern fields and lower gravity from the fields in Illinois, Oklahoma and Texas. The gravity has nothing to do with the lubricating qualities of the oil, although such is a general impression.

DETERMINING THE VISCOSITY

THE VISCOSITY is determined by means of an instrument called a viscosimeter. The time in seconds for the oil to run through the standard orifice of the viscosimeter is called the viscosity. The operation of the Tagliabue viscosimeter is as follows: The instrument measures the viscosity at 70 and 212 deg. F., the lower temperature being used for light-bodied oils and 212 deg. F for heavy cylinder oils. If an engine oil is to be examined, the 70 deg. tip is screwed into the bottom of the oil cylinder, and the water surrounding the cylinder is brought to 70 deg. The oil to be tested is then heated or cooled to 70 deg. and 90 c.c. of the sample is then strained and poured into the oil cylinder. The oil is then stirred well with a thermometer to make sure that the temperature has not changed, as it is important to secure and maintain an even temperature throughout the test. The thermometer is removed from the oil and the cock opened, the time being noted at the same instant, 70 c.c. of oil are allowed to run into a graduated flask furnished with the instrument, and the time again noted. The time in seconds $\times$ 2 gives the viscosity of the oil.

Cylinder oils are run in the same manner, another tip, however, being used, and steam instead of water surrounding the oil cylinder. By comparing the viscosities of several different samples that may be furnished by competing firms, an oil that will give the same results in practice as the one that has been used, can be selected without guesswork or experiments on costly machinery.

FLASH AND FIRE TESTS

THESE ARE determined by heating about 3½ oz. of oil in a metal cup, which is fitted with a thermometer for taking the temperature of the oil. The Cleveland Open Tester is a favorite among oil chemists, but good results can be obtained with a 4-oz. iron crucible with a thermometer ("bulk immersion"), graduated to 700 deg. F., and a Bunsen burner. About 100 c.c., or 3½ oz., of oil is placed in the cup and the Bunsen burner lighted. The cup is placed in a ring stand and the flame placed under the cup. The flame is so regulated that the oil in the cup will rise at the rate of 15 to 20 deg. F. per min. The thermometer is inserted in the center of the cup with bulb immersed in the oil, but not touching the cup. A test flame, about the size of a match head from a small taper or gas flame (from a fine tube), is passed diametrically across the surface of the oil when the thermometer indicates a temperature of 275 deg. F. The test

flame is applied for every 5 deg. F. rise in temperature until the vapor from the oil ignites momentarily, the temperature indicated by the thermometer is taken as the flash point, the temperature of the oil is raised and test flame applied till the oil burns freely; this temperature is taken as the fire point.

Gravity Test

The specific gravity, or degree Baume, is taken with a hydrometer. The oil is placed in a glass cylinder and the hydrometer inserted. The reading of the hydrometer scale is often at the point where the stem emerges from the oil. A temperature correction is made if the oil is at some other temperature than 60 deg. F., as this temperature is taken as a standard of reference in Baume determinations.

There are several other determinations that are made on oils for special purposes, such as the evaporation and cold tests. The cold test is the temperature at which the oil will just flow; this is easily obtained by cooling the oil with a mixture of ice and salt till it is solid and then gradually warming until the oil will flow; this temperature is called the cold test.

The presence of animal or vegetable oils in a lubricating oil is determined by adding a small piece of caustic soda to 5 or 10 c.c. of the oil contained in a test tube, and then heating over a Bunsen burner for a few minutes. If the oil after cooling is solidified or the body much increased beyond that of the original sample, there is animal or vegetable oil present.

Tar is present in some oils and is not a desirable constituent in lubricating oils. The presence of tar or foreign matter can be determined by adding 95 c.c. of 86 deg. Baume gasoline to 5 c.c. of oil and setting aside in an oil sample bottle for an hour; if tar be present, it will settle to the bottom.

Mineral oils should be free from acid; this may be tested by shaking equal parts of oil and distilled water together and testing the water with blue litmus paper, which, if acid be present, will turn red. A small sample of oil placed on a polished piece of copper should not show any green color or corrosion of the copper after standing for 24 hr.

There are several ways of noting the lubricating value of the oil by testing on machines in the plant and noting the temperature of the bearings when using different oils. The amount of oil necessary to feed to the steam cylinder will give some indication as to the efficiency of a cylinder oil.

The idea in correct lubrication is to keep the rubbing surfaces out of physical contact, by means of a thin film of oil. The oil to do the work properly must have enough body to keep the surfaces apart, but not enough to retard the moving parts; a heavy cylinder oil would be out of place on a high-speed shaft, adding to the friction, rather than reducing it. All things considered, the thinnest oil that will stay in place should be used to secure the best results; this can best be found by practice; too thin an oil allowing the metallic surfaces to come in contact and causing a marked rise in temperature or, in other words, a hot bearing.

As heat reduces the apparent viscosity of an oil, oils that are used for hot work, such as steam cylinders, must have a much higher viscosity than would an oil to do the same work, were the hot parts cold. For this reason under some conditions it is advisable to increase the viscosity of an oil by the addition of more or less oil having a higher viscosity. The addition of 10 to 15 per cent of cylinder oil, often improves a light engine oil that is subjected to unusual conditions, such as heat or heavy load.

Lubricants for Special Purposes

The addition of 3 to 5 per cent of good graphite to bearings that are new or that continually run hot, is found to be of benefit. Graphite helps smooth down the rough surfaces and puts a high polish on the bearing surface, which materially helps the oil in lubricating the surface.

For light pressures and high speeds, engine and spindle oils give the best results. Motors, dynamos, shafting, and most ordinary machinery, come under this class. For thread cutting the addition of ⅓ by volume of commercial lard oil will give good results. A good drilling compound is made by adding from a pint to a quart of the compounded lard oil (⅔ engine oil, ⅓ lard oil) to 1 gal. of water containing 5 lb. of soda to 40 gal. of water.

SPECIFICATIONS FOR OILS

NAME	Color	Specific Grav. in deg. Baumé	Cold Test deg. F.	Flash deg. F.	Fire deg. F.	Viscosity at deg. F.
Steam Cylinder Oil Steam Cylinders	Green	25.	32.	536.	599.	171 @212
Car Journal Oil Conveyors, etc.	Black	19.5	27.	401.	437.	122. @212.
Engine Oil Motors, Shafting, General Machine, Lubrication	Red	23.5	7.	374.	419.	228. @100.
Auto Oil Air Compressors, Motors, Gasoline Engines	Lemon	25.5	0.	392.	437.	205. @100
Mineral Sperm Oil Type Machines, Sewing Machines, Light Machinery in general	White	29.5	—	356.	392.	99. @100

For air compressors a high flash and fire oil should be used; low flash oils give off volatile matter, which may cause explosions and also give trouble, due to carbonizing of the valves. A good auto oil will be found to be satisfactory, although due to the name "auto" the price is apt to be high. Auto oils are high-grade engine oils, having high flash and fire points, a good body, and a high color, due to filtration or bleaching.

Ammonia compressors require an oil with a low cold test—that is, an oil that flows readily at low temperatures. For conveyors and other rough machinery, a black car journal oil or grease is satisfactory. For high steam pressures and superheated steam, a straight mineral oil flash 525 to 550 deg. F. is best; for low pressures in the presence of moisture, addition of 1 to 7 per cent tallow and lard oil is used, but it does not add much to the value of the oil, except to increase the cost.

Gas engines require an oil which is clean, high flash and fire, and also one that will be consumed in the cylin-

der with the least production of carbon, as more or less of the oil on the cylinder wall burns with the charge; such an oil should flash to 400 deg. F., or above.

Herewith is a table giving data on the gravity, flash, viscosity, and the uses of several mineral oils. These oils are in actual use and are giving excellent service. The viscosities were taken on 2 different instruments, the light oils being run at 100 deg. F. and the heavy oils at 212 deg. F. Comparisons of viscosity, as given in the table, may be made to the viscosity on any other instrument, by using the viscosity of water as a basis for the comparison. The instrument used for heavy oil at 212 deg. gives viscosity of water at 212 deg. F. as 28, and the instrument for light oils gives viscosity of water at 100 deg. F. as 26.

Methods of Buying Oils

"We Buy Everything by Specification." By Edward H. Robie

ONE hears this phrase more and more often these days, especially from men connected with large and successful concerns—big corporations which are making money. The modern engineer is always taught, when he is taught at all, that he should first know just what he wants and then should see that he gets it. Furthermore, it is claimed that this excellent advice is best carried out by buying under strict specifications. Without doubt, this is an excellent idea, in most cases, but it will not always prove advantageous, as often the specifications are not what they should be. I will try to show, for example, why the ordinary power-plant owner, running, say, less than 2000 hp., should not try to issue complete specifications for the lubricating oil used.

To begin with, the average engineer does not know what to specify. Right offhand, now, do you know from actual experience what the specific gravity, color, cold test, flash point, chemical composition, viscosity, etc., of the oil for each of your purposes should be? If not, what do you do? Why, find out what someone else is specifying and use his figures. He has probably taken his out of "a book" and they are in nowise adapted to his requirements or yours, either. Most of the specifications commonly accepted as "standard" are, more or less, unsatisfactory. For example, the Navy Department specifications have been changed often and are still not perfect by any means. On the other hand, the specifications of the Pennsylvania Railroad, I understand, were made about 25 yr. ago and many stocks have come into use since then, which, though not meeting these specifications, may, nevertheless, be satisfactory and often cheaper.

It may seem a waste of printer's ink to say that different oils are required for different purposes; but there are many engineers who, as suggested above, use specifications which do not apply to their plant, or else use the same oil for all purposes. Oftentimes a cheaper oil would be as satisfactory for ¾ of the work. Superheated steam requires a different oil from saturated steam; a high-speed engine, a different oil from one running at low speeds, etc.

Suppose you have found a satisfactory oil which you have had tested and, therefore, think you know what the specifications should be. Let us consider the different properties.

Specific Gravity

About all this indicates is the origin of the oil. Another oil of different specific gravity may be equally efficient. Western oils have a paraffin base and have a higher specific gravity than Eastern oils. Lubricating oils come from Pennsylvania, West Virginia, Ohio, Texas, California, Russia, etc. Pennsylvania crude stocks are usually considered by far the best.

Color

Dark green oil, so much favored and so often specified, means that the tarry matter is probably less than 0.2 per cent. In order to keep the percentage of tarry matter down, care must be used in refining; the stock must not be overheated or refined from dirty crude. The color means nothing regarding the lubricating value of the oil.

Viscosity

This property is determined by means of an apparatus called a "viscosimeter." There are several different kinds—the Tagliabue, Doolittle, Redwood, Saybolt, Engler, etc., and all give different results on the same oil. To mean anything, the name of the instrument used should be given in connection with the reading. Western oils, as a rule, have a higher viscosity than Eastern oils. Open bearings require a heavy viscous oil, while machinery running around 3000 r.p.m. must be lubricated with a light-bodied oil.

Many foreign investigators, including Ubbeholde and Fea, have carried out exhaustive investigations and found that all oils of equal viscosity give the same coefficient of friction at any given temperature.

Flash and Fire Point

The test for flash and fire point is performed in several different styles of apparatus, which may be divided into 2 general types—the open and closed. The closed type will, in general, give a lower flash point than the open. The thermometers commonly used in determining flash points are uncorrected for immersion and this introduces a perceptible error, no matter which type is used. Given the flash point, the fire point means practically nothing, as it bears a practically constant relation to the flash point. Western oils have about the same flash tests as Eastern.

The flash point really measures the temperature at which an oil gives off a certain amount of vapor—but the vaporization depends on other factors besides temperature; the pressure, for instance. Whereas the test is performed at atmospheric pressure, the oil is used under, perhaps, 100 lb. pressure, and with a cylinder temperature of 400 deg. an oil with a flash point of 400 deg. might, therefore, vaporize scarcely at all under actual working conditions. The fact that the oil is surrounded by steam instead of air will also affect the degree of vaporization.

With superheated steam there is a difference of opinion as to what the fire and flash point should be. Some authorities state that oils for this work must

have a high test. Others believe that it should be low—that a certain amount of volatile matter should be present to saturate the steam properly for lubrication. European engineers demand high test stocks for superheated steam.

Cold Test

This is ordinarily of little importance where the oil is to be used in an engine room. There are 2 methods of running this test, giving different results. The method to be used must be stated to make the figure mean anything.

Lubrication Test and Coefficient of Friction

This is perhaps the most important point, since it is lubricating quality that is being purchased, and an oil, suitable in other respects, which has the highest lubricating value, is the best. It must be borne in mind, however, that here the same condition applies as in the case of the flash test; i.e., that the test as usually performed, with the Thurston testing machine, for example, is not made under actual working conditions. It takes no account of the action of steam. The figures obtained are, therefore, inaccurate.

From the above it is clear that the physical characteristics of an oil, as ordinarily determined, give little real information on the stability of the oil for lubricating engines—in other words, oils with the same physical tests (as ordinarily conducted) may possess quite different lubricating values. In short, physical tests are old-fashioned. Nowadays refiners can concoct an oil to meet almost any specifications and at the same time manage to leave all the lubricating value out of it.

Now let us consider various oils from a chemical standpoint. This immediately brings up the question of whether animal oil should be added to a mineral stock. The use of animal oil dates back from the time when the petroleum stocks were of such low grade that it was necessary to add animal oil. It is now generally recognized that animal oil should at least be kept out of an engine using superheated steam, as at high temperatures glycerin is liberated and free fatty acid remains to attack the metal, causing gummy deposits and leaky pistons. If the superheat is not high, however, a small percentage of animal oil may be used and such a combination has been recommended where the equipment is poorly kept and where the rings, valve seats, etc., are worn.

An animal oil tends to emulsify; this a pure mineral oil will not do. If there is trouble from emulsification, the oil is not always to blame, however, as foreign grease, or water from a boiler in which softening compound is used, may get into the cylinder and cause trouble, forming regular soapsuds in the oil, where it is used over and over again.

Chemical decomposition is more apt to set in if animal oils are used in circulating systems where the oil is continually exposed to heat, moisture, air, etc. There may also be decomposition with some oils if they come in contact with brass, copper, galvanized iron, etc. In short, the uses to which the oil is to be put must always be considered.

If what has been said above tends to cast some doubt as to just what to specify, I have at least partly accomplished my purpose. Is there no way, then, for the small operator to purchase oils intelligently? Assuredly there is.

The plan is this: For each purpose for which oil is required, select, say, half a dozen standard brands put out by reputable manufacturers, which seem to be the most likely to fulfill requirements of price and quality. Test each of these out for a day, 2 days or a week under actual operating conditions and see which gives the best results. Or, better yet, throw the load off the engine and take cards using the various oils. The indicated horsepower will then depend on the friction. Here are some results obtained in this way by C. H. Garlick on a 125-hp. engine.

Using 2 drops of good oil per minute, friction load = 18 hp.

Using no cylinder oil whatever, friction load = 27 hp.

Using 12 drops ordinary oil per minute, friction load = 24 hp.

Bearing oil can be tested by using a certain amount for a certain time and testing the temperature of the bearing with a thermometer.

Tests like the above are easy to run and furnish accurate data regarding the lubricating value of oils under operating conditions. In selecting the oils care should be taken to get recognized brands from reliable concerns that will keep the brand of constant quality, otherwise the tests would have to be repeated often.

Price is not always an index to quality. Supply and demand determine price, not quality.

Don't use the same oil on a boiler feed pump that you do on a high-speed turbine; it is too expensive.

Large users who can afford to have an oil specialist will no doubt find it advantageous to buy oil by specifications. But the oil specialist must know the kind of machines on which the oil is to be used, the service conditions, the method of applying the oil, the source of oil and the process of refining in order to make up intelligent specifications. Many specifications are unjust because they do not coincide with the methods of manufacture of some concerns.

Equally good results may be obtained by oils from different fields or refined by different methods. It is therefore not entirely correct to test an oil in service and then prepare specifications based on the chemical analysis of an oil which has been found good. This is usually done in Europe. Laboratory tests are only indications to exclude oils which are obviously of inferior quality.

The attainment of efficiency is a simple, common-sense matter. Keep your eyes open; study methods and where they appear to you to be capable of improvement, study out practical remedies and apply them. If you get the habit of mind that enables you to observe, to think straight and to put your thoughts in clear, concise, simple language, you are an efficiency expert, whether you are concerned only with your own efficiency or with that of others.—Dodge Idea.

There is nothing finer in the whole scheme of creation than a piece of worth-while work well done.—Steam Machinery.

Furnace and Boiler Room Efficiency

SELECTION OF BOILERS AND ARRANGEMENT, POINTERS ON COMBUSTION, IMPORTANT INSTRUMENTS FOR THE BOILER ROOM. BY M. T. KIMMAN*

THE question of furnace efficiency is of great importance in the successful operation of a steam power plant; but it has often appeared to me, that coupled with furnace efficiency should be "boiler room efficiency," but for the objects of this paper we can discuss the 2 subjects separately.

Webster defines the word "efficient" as "Producing, or causing effects, or results"; in conjunction with producing, or causing effects, however, it has come to be understood that not only must effects be produced, but results must be obtained with the greatest degree of economy, consistent with good service, and this economy should extend not only to use of coal and supplies, but to first cost of installation, material, labor and time, to accomplish a given result.

To commence with, the engineer who designs a boiler room should select the type of boiler to be used, not

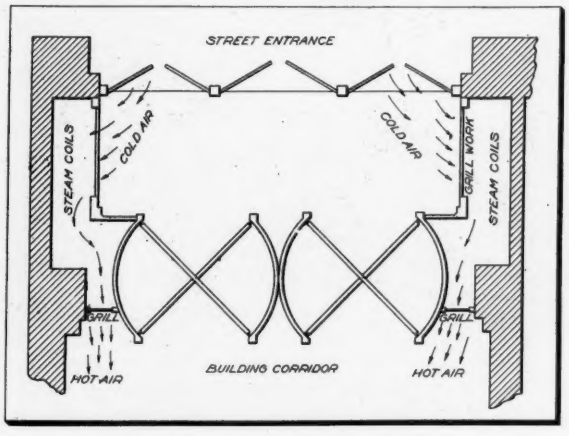

FIG. 1. MEANS RECOMMENDED FOR HEATING BUILDING CORRIDOR

only with the view of producing steam with the minimum consumption of coal, but also as to the amount of labor in operating and cleaning the boilers. For one service it may be desirable to provide water-tube boilers in large units, particularly if the maximum loads are to be carried for the longest periods of the 24 hr. For another plant it may be best to provide more boilers in smaller units, if the load to be carried is variable, and unevenly distributed throughout the 24 hr. Some boilers, even in large units, can be cleaned inside and out in 4 or 5 hr.; other types may require 4 or 5 days, yet this additional labor factor may be compensated for in higher economy, or the labor may be available for other work when not engaged in boiler cleaning. The length and direction of the smoke connection between the boilers and chimney does not always meet with the attention it deserves. A long breeching should be avoided, and it should have a decided rise from boiler to stack. The efficiency of many boilers could be increased materially if the uptakes were properly designed.

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The force of gravity should be utilized for the delivery of the coal supply. The ideal condition is one where the coal falls from the source of delivery into a storage bin, from there directly into the furnace hoppers, and the ash drops into receptacles, which are hauled away when filled. Not all these conditions can be realized in all plants; but most of them can, and often not sufficient care is bestowed on this feature of design.

The writer has in mind one boiler room, which was designed with coal and ash handling machinery to the value of $18,000; but by merely turning the boilers around to front the other way, the coal was delivered by gravity, the coal conveyor eliminated, and its operating and maintenance expense saved.

NATURAL VENTILATION

TOO OFTEN designing engineers do not give sufficient attention to utilizing the natural forces at our disposal; they cost nothing and are always on the job. For example a great deal of money is invested in artificial ventilation for basements and sub-basements, yet with a little study of the movements of air, the tendency of

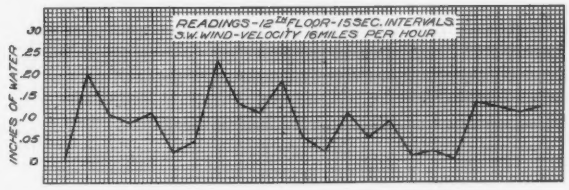


FIG. 2. CHART OF AIR PRESSURE ON TWELFTH FLOOR

cold air to drop, and hot air to rise, better results can be obtained at no expense except for ducts, saving in both first cost and operating expense.

The foregoing is not intended as a criticism of designers, so much as to call engineers' attention to how savings can be made, and efficiency increased.

Utilizing exhaust steam and hot water frequently does not get the attention that it merits. It is well to remember that every pound of exhaust steam and hot water represents an outlay in coal and labor, and it is well worth the engineer's time to find uses to which it may be put to recover the heat units it carries, instead of letting the one escape into the atmosphere and the other into the sewer.

DETECTING A WASTE

IN A certain power plant great care was taken to run all cooling water from air compressors, and the furnace water backs, as well as the discharge from traps to an open heater; but the water bills were considered excessive. A little study discovered the cause.

As stated above, all cooling water was piped to the heater, also all returns from heating system, traps, jackets, etc. The heater was also supplied with a 2-in. make-up valve from the city mains, with float regulation. The discharge from the heating system through the

vacuum pump was not constant, therefore, the make-up feed valve was often in operation, and it was found that, frequently, just after this valve had filled the storage part of the heater, the vacuum pumps suddenly discharged so large a quantity of water that the automatic overflow valve opened, and the water promptly found its way into the sewer. This water in its passage through the heater had condensed considerable exhaust steam, and taken up heat from it. An additional storage tank was provided at small expense, with the result that there was more exhaust steam available for heating and less hot water in the sewer.

In another plant a refrigerating machine was installed which, besides cooling boxes, was required to supply one ton of pure ice per day. A 3-in. pipe was connected to the exhaust main, and the steam piped to a condenser; the resulting condensed water was then filtered to remove cylinder oil, passed through a reboiler and then to a cooling tank from which it was drawn into the freezing tanks. The engineer found that where before this installation he always had sufficient exhaust steam to heat the building, he now had to use live

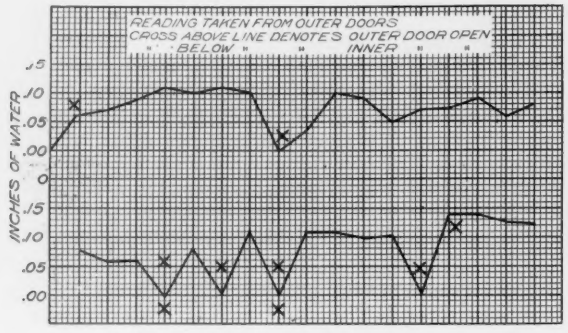


FIG. 3. CHART OF AIR PRESSURE AT STREET LEVEL

steam to make up the deficiency. It was then decided to cut off the 3-in. exhaust line, and take the discharge from 2 steam traps which were run to discharge into the reboiler. This proved sufficient for the requirements and saved the water before used in the condenser and left sufficient exhaust steam to heat the building, saving the live steam that was being used.

The saving and utilizing of these losses tend to the efficiency of the boiler room.

Combustion in the Furnace

The next point, furance efficiency, requires that the engineer in charge should have some knowledge of the theory of combustion.

Combustion is a process in which 2 or more elements enter into chemical union and liberate heat and light.

The elements employed are oxygen, hydrogen, nitrogen and carbon (or for our purpose coal). Now to form chemical union there must be chemical affinity, and chemical affinity acts only at insensible distances; it is necessary to bear this last in mind as on this depends perfect combustion, which alone tends to furnace efficiency and which is the most difficult to attain in the chemistry of the boiler furnace.

Coal in itself is not combustible, nor will it burn. That is to say, coal alone will not ignite. It must be brought in contact with oxygen before it becomes useful as fuel. When coal is thrown into the fire box, we say it is consumed, which is true as to the coal, but we have only changed its nature into various gases. The products of perfect combustion are steam and carbonic acid, both invisible.

The products of imperfect combustion are steam, carbonic acid, smoke, carbonic oxide and other combustible gases. These products of imperfect combustion are also invisible with the exception of the so-called smoke or carbon, and often the 5 invisible ones are escaping from the stack without the carbon or smoke. These are the ones we should aim to utilize in order to secure furnace efficiency.

Bituminous coal is what its name implies, carbon and bitumen, and when it is thrown into a live fire it first commences to distil the bitumen, which burns like a pitch or oil. This must all be burned or distilled off before the carbon or coke will burn, and this volatile

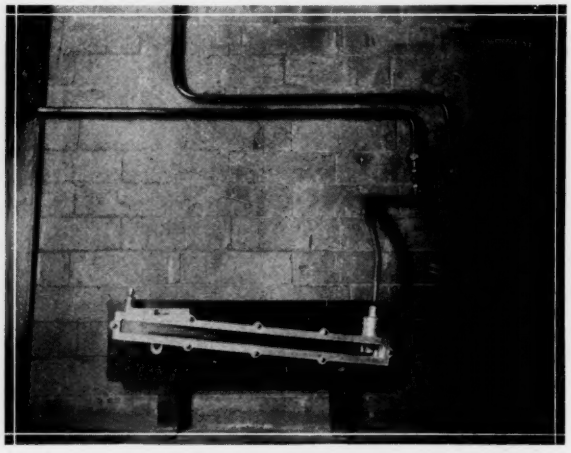


FIG. 4. DRAFT GAGE CONNECTED TO SHOW DRAFT IN 3 PARTS OF BOILER SETTING

matter, as it is called, is what gives us the most trouble in the prevention of smoke, and the securing of perfect combustion. In distilling the volatile matter from the coal into a gas, a great deal of heat is taken from the existing fire bed, which is latent in the gas until a sufficient quantity of oxygen from the air is admitted, and not only admitted but so finely divided as to enter into chemical union at insensible distances. When the gas becomes ignited it gives up the heat it first absorbed, and also the heat from its own combustion. This is the problem for the engineer to work out, and the closer he approximates perfect combustion, the higher the furnace efficiency.

To accomplish this, he must first have a suitable grate on which the fuel bed rests, and to supply air for the combustion of the coke after the volatile matter has been distilled. A grate should have as much air space as possible consistent with strength, and it does not pay to sacrifice too much for durability; it is economy to be satisfied with less length of life of grates in order to secure better air-space division.

Next, the air space should be finely divided, not a wide bar and then an equal opening. The finer the coal and air spaces in the grate, the quicker the chemical

action, and easier for the different elements to get together. A fire should never be disturbed with a poker on top, if hand fired, nor should a slice bar be used, except in an emergency. When it is necessary to slice a fire it is time to clean it out, and this should be done.

While the coke is burning with a supply of air through clean grates, we must be prepared to admit a volume of fresh air over the fire for the ignition of the volatile matter distilled from fresh fuel. The fresh coal reduces the temperature before it becomes active, and as it begins to volatilize and the gases are liberated and expand, they, in turn, take up large quantities of heat by their expansion; therefore, the smaller the quantity of fresh fuel supplied at one time, the better.

Air leaks in the setting, and heat radiation from them are frequent causes of loss in efficiency. From the nature of the materials used it is almost impossible to prevent some air leakage; but the loss can be modified to a large extent, first, by care in the construction, and, second, by a coating of asbestos cement covered with canvas and painted, or, if for various reasons this cannot be done, several coats of paint over the brick walls and mortar joints will well pay for their application.

Another source of loss is due to underloaded boilers, or boilers working below their rating. Efficiency can be better attained by a furnace burning 30 to 40 lb. of coal per square foot of grate than in one burning 15 to 20 lb.

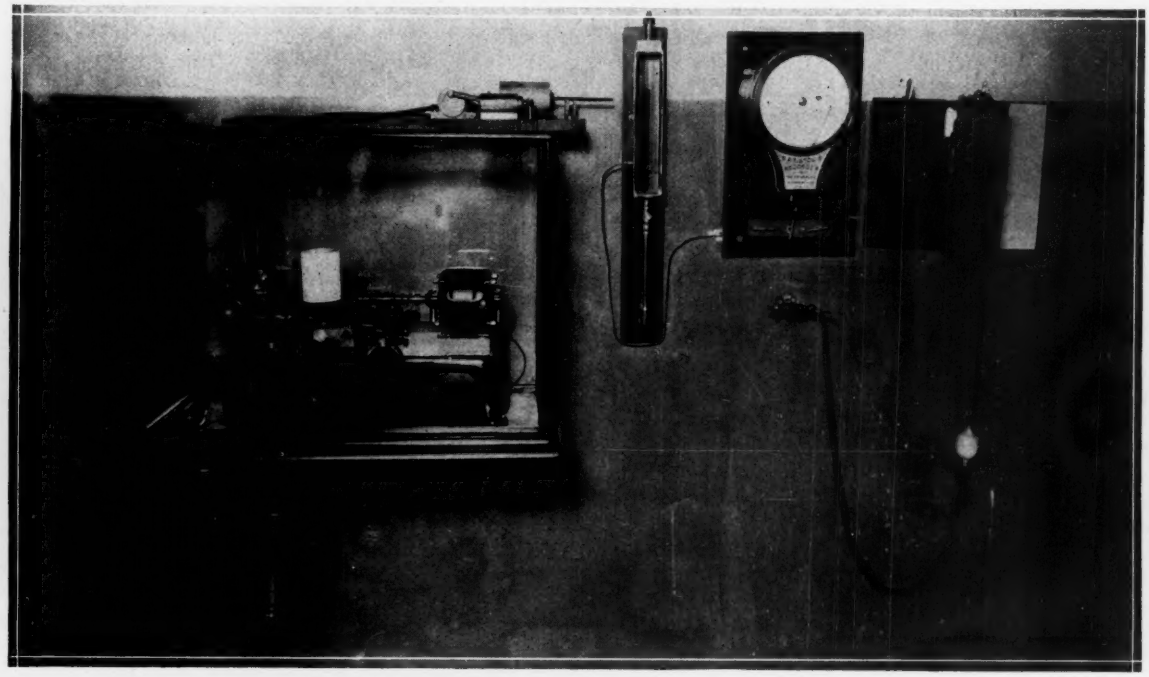


FIG. 5. INSTRUMENTS WHICH HAVE PROVED MOST VALUABLE IN SECURING ECONOMY IN THE BOILER ROOM

Every boiler should be equipped with a draft gage, and the draft regulated to suit the requirements of the load on the boiler; the thickness of the fire bears a close relationship to the amount of draft needed. The draft should be regulated by the damper in the uptake instead of the ash-pit doors, as by the use of the damper the suction is always just sufficient to supply the necessary air through and over the fire, instead of through leaks in the setting, which are detrimental to efficiency.

Theoretically, for perfect combustion a pound of coal requires about 12 lb. of air. This pound of coal contains, by weight, 77 per cent nitrogen and 23 per cent oxygen. The nitrogen is not required for combustion and it remains unchanged, but we cannot get the oxygen without it. It takes up heat and escapes with the other products of combustion, and forms one of the losses of combustion. The best that can be done is so to regulate the thickness of the fire, draft and air supply, as to furnish as little excess air as will supply the oxygen required.

Today no plant is considered complete and up to date unless it is equipped with feed-water regulators, yet a serious loss can be occasioned by the improper use of these useful devices. The duty of the governor is to shut off the steam supply to the feed pumps when the water reaches a certain level. If the pump is of the correct size and the speed of the pistons looked after, this forms an ideal condition. Unfortunately some governors are of the wide-open and tight-shut type, which gives excessive speed when the governor opens up, with the result that the water supply is intermittent, necessitating uneven firing to keep up steam, and an uneven steam line.

Another frequent serious loss is the waste of carbon in the ashes. This is occasioned in chain grates by excessive grate speed, or broken or defective links; on inclined automatic stokers, by broken or defective grates; on hand-fired furnaces equipped with shaking grates, by carelessness in shaking.

To sum up, the boiler room is a manufacturing plant for the production of steam, and, like all factories, it requires constant vigilance on the engineer's part to keep down the inevitable losses. To attain efficiency, boilers should be overloaded rather than underloaded. The thickness of the fire and a proportionate draft must be carefully watched. An examination of the ashes should be made at the end of each watch, and the amount of carbon in the ashes ascertained; if excessive, the fireman or watch engineer's attention should be called to it at once. The setting of the boilers should be frequently examined, and all air leaks stopped. The fire surfaces of the shell and tubes must be kept free from soot and ash. The feed-water should be delivered uniformly, the steam maintained at an even pressure. The flue gas temperature should be as low as is consistent with the steam pressure carried. Frequent tests of the flue gases should be made to ascertain the nature of the escaping gases, and if the boiler feed lines are not equipped with measuring tanks, a meter should be installed so that the evaporation per pound of coal can be frequently ascertained. Meters for hot water are not always reliable, but sufficiently so for comparison.

Figure 1 is a sketch of the entrance of a building, which typifies a case in which a natural force is used to create a blast-heating system for a large building corridor, always a difficult place to heat satisfactorily. A tall building acts in the same manner as a chimney—that is to say, a current of cold air is constantly entering at the bottom, through doors and windows, and warm air escaping at the top, through skylight ventilators, windows, etc.—but, unlike a chimney, a building is covered with a roof, and the result is that pressure builds up, i.e., more air enters at the bottom by the constant opening of doors, than can find its way out through leaks and open windows at the top floor; therefore, the outflow of hot air commences lower down than the upper story, and varies with the outside temperature, and velocity of the wind. In one test the air was found flowing *out* as low as the twelfth floor of a 20-story building.

In the drawing, the outside doors are ordinary hinged doors swinging out, and opening on a vestibule entirely closed from the corridor by a set of revolving doors. The only way for the air pressure to equalize itself is through the grille work over the steam coils, and out through the grille work placed on the corridor side of the revolving doors.

The air pressure is always less on the lower floors than outdoors, and the instant an outside door is opened, the hot air rushes in with a velocity that equals the ordinary fan blast.

The chart, Fig. 2, shows the wind pressure in inches of water on the leeward side of the building with a 16-mile wind blowing; the instrument being placed inside of a closed room, registering 0 inside, and the collector placed through an opening in the window frame.

The chart, Fig. 3, shows the air pressure at street level outside, with doors closed and opened at intervals, the X above the line shows outer doors open, X below the line shows inner doors open. This clearly shows the intake of fresh air each time the doors are opened.

The photograph, Fig. 4, shows how a draft gage can readily be connected to show the draft in 3 or more different parts of the setting, giving the engineer an opportunity to ascertain the effect of baffling, and to detect obstructions to the chimney draft. In this instance, one connection is run into the furnace over the fire, and this is most used; the next in the first pass, and the third just below the damper in the last pass. Figure 5 is a view showing smoke recorder on the left, portable machine for flue gas analysis on the right, and recording thermometer indicating temperature of flue gases.

Figure 6 shows a home-made instrument used for measuring the air pressure in buildings, and was designed and built by C. J. Harden. The machine is simple, consisting of a receptacle holding water and an inverted float, connected through a pivoted beam with the rack of a steam gage pointer. The dials are graduated in inches of water and calibrated by a differential draft gage. The instrument is very sensitive, and in use is enclosed in a tight box, only the dial showing. An ordinary draft gage is too slow to follow the rapid changes in pressure, and the readings are too fine.

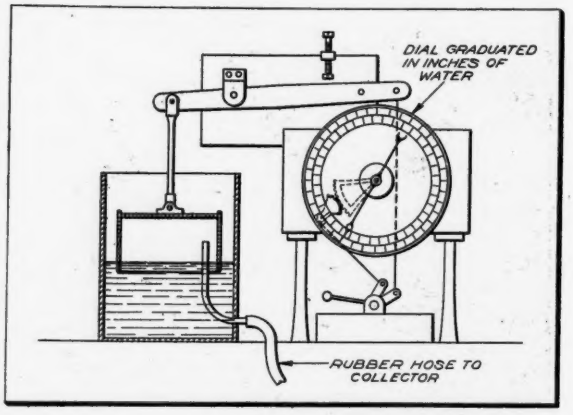


FIG. 6. INSTRUMENT FOR MEASURING AIR PRESSURE IN BUILDINGS

The engineer should understand and keep constantly in mind that the boilers should come first. It is in the boiler room that the one big item of expense—coal—is used. A leaky valve or piston in the main engines will increase the steam consumption and the corresponding cost, but not nearly so much as can be done by carelessness in the operation of the furnaces. It is in the boiler room that a perfect system of operation must be devised and adhered to and constantly watched. If this is done, substantial gains will follow.

AWARDS of medals for advance in safety provision were made on Dec. 12 by the American Museum of Safety as follows: Scientific American Medal for life saving device invented within 3 yr. to Welin Marine Equipment Co., for devices for saving life at sea. Dr. Louis Livingston Seaman Medal for progress in hygiene and sanitation to the United States Steel Corp. Rathenan Medal for progress in the field of electrical invention to General Electric Co. Travelers Insurance Co. Medal for greatest advance made by an American employer in protection of life and limb of employes to New York Telephone Co. A special medal on this basis is awarded to Allgemine Electricitats Gesellschaft.

Flue Gas Apparatus

INSTRUMENTS FOR DETERMINING THE THOROUGHNESS OF COMBUSTION; CO_2 IMPORTANT IN FLUE GAS ANALYSIS

FLUE gas analysis offers a ready means of determining the quality of combustion, upon which efficiency in steam production is directly dependent. When combustion is complete, the whole of the carbon and hydrogen, which are the chief combustible elements of fuel, unite with the oxygen of the air to form carbon dioxide (CO_2) and steam or water vapor (H_2O), respectively. Samples of flue or waste gas, however, contain carbon dioxide, oxygen, carbon monoxide, nitrogen, unburned hydrocarbons, and occasionally some hydrogen, but a volumetric analysis of the CO_2, O and CO, is usually sufficient to indicate the thoroughness of combustion. Such an analysis can be conveniently made with a portable device known as an Orsat.

All of the various portable forms of hand-operated apparatus for the analysis of waste gases operate on the principle employed in the original Orsat, differing only in details of construction. The apparatus consists essentially of a measuring tube or burette, a water bottle, 3 absorption pipettes, and the necessary cocks and tube connections. The measuring tube, which is surrounded by a water jacket, to maintain the gas at a uniform temperature, usually holds 100 cu. cent. and is graduated to read in per cent. The water bottle, which is connected to the bottom of the burette by flexible tubing so that it may be raised and lowered, contains clear water (preferably distilled), and is used for the purpose of passing the gas back and forth through the absorption vessels. The pipettes contain a 33 per cent solution of caustic potash, an alkaline solution of pyrogallic acid, and a hydrochloric acid solution of cuprous chloride, which absorb, respectively, CO_2, O, and CO. Each pipette is connected by short tubing equipped with a glass or pinch cock, to a common tube or yoke attached at one end to a tube leading to the gas supply and at the other end to the measuring tube.

To analyze the gas, a measured volume representing an average sample, is forced first through the pipettes containing caustic potash, and the contraction in volume measured; then through pyrogallic acid and last through cuprous chloride, contraction being measured after each operation. It is essential that the above order be followed, otherwise the results will be worthless.

Treating tubes of different design are used, some consisting of 2 glass vessels connected at the bottom by a glass tube, others being made of 2 tubes, one of which is inverted and placed within the other. The latter type requires little space, is easy to charge with solution, and will withstand reasonably rough handling.

In the analysis of flue gases, it is necessary to obtain a representative sample, as errors often result from the inability to secure an average sample of the gases in the different parts of a flue or stack.

CO_2 Recording Apparatus

SINCE CARBON is the principal combustible of coal, and as the loss, due to unconsumed combustible gases, carbon monoxide, hydrogen and hydrocarbons, is invisible and difficult to determine, it follows that for most practical purposes a determination of the amount of carbon dioxide alone is an adequate index or guide to the amount of heat being wasted up the stack, and should be made continuously in order to obtain the highest continuous boiler efficiency. The percentage of CO_2 in flue gases may be readily determined by mechanically operated devices which require only a brief period of 2 or 3 min., no attention being necessary.

With these automatic devices, usually a small stream of water furnishes the power, which draws a current of gas from the uptake or chimney, a measured volume of the gas being trapped off in a floating chamber and forced through a solution of caustic potash into another chamber which is connected with a recording or indicating mechanism that shows the contraction in volume or the amount of carbon dioxide absorbed. Recording mechanisms are usually so calibrated and adjusted that the pen travels to the top or zero line on the chart when only atmospheric air is passing through the apparatus, and nothing is absorbed by the potash, but when the gas contains carbon dioxide, this is absorbed and the diminished volume causes the pen to travel a shorter distance on the chart in proportion to the amount of CO_2 removed.

This form of apparatus, after being started, requires no attendant and shows what is transpiring in the furnace, not only at the time at which the sample is taken, but continuously. It must, however, be kept always in good condition, the connections intelligently made, and its indications considered in connection with data as to air supply and draft.

Simmance-Abady Combustion Recorder

PRECISION INSTRUMENT CO., DETROIT, MICH.

THERE are 2 types of this instrument, one which records CO_2 alone, and another which records both CO_2 and draft.

When in operation, water entering through X is allowed to flow through the hollow valve stem, E, Fig. 1, from the small reservoir, K, which has the safety overflow 00. In siphon tank A, a weighted float, B, which is attached by means of a chain, C, to bell, D, of the extractor, rises with the water allowing the bell, D, to fall. At the top of its stroke the float, B, raises the valve stem, E, thus tripping the valve, and momentarily flushing the siphon tank. The water now siphons out of A through siphon tube, G, allowing the weighted float to fall, and in so doing draws up the water sealed extractor bell D, in which is created a partial vacuum, and into which, therefore, gas flows from the flue through P and H.

Next, the weight of the water which has flowed from the siphon tube, G, into the small apartment beneath it, overcomes the weight of the counter, Q, and closes the balance valve, H, thereby cutting off a definite sample of the gas. Water is released from the small pot in time to allow the valve to open at the proper interval.

As water flows continually into tank A, the float B rises again, allowing the extractor bell, D, to sink. As it sinks it will be seen that the gas in bell D, is first reduced to atmospheric pressure, and is then actually under pressure; the volume of the gas is then forced

into vessel M, where it bubbles up through the caustic potash (the CO_2 being absorbed), and then into the recorder, J, raising the bell.

Scale N is graduated from 100 per cent at the bottom to zero per cent CO_2 at the top, and the capacity of the bell D is such that when the apparatus is run on air, containing practically no CO_2, the total volume is transferred to the recorder bell, J, which in this case rises to the zero point. When flue gas is admitted to the apparatus, exactly the same quantity (that is, enough to send recorder bell up from 100 to 0) is passed from the extractor bell, D, but on the passage of the gas the CO_2 is absorbed by the caustic potash in the iron vessel, M, reducing the volume of the gas so that the recorder bell, J, will not rise to its full height. It rises automatically as far as it will and a pen then marks its final position on the chart, thus recording the percentage of CO_2 in the gas.

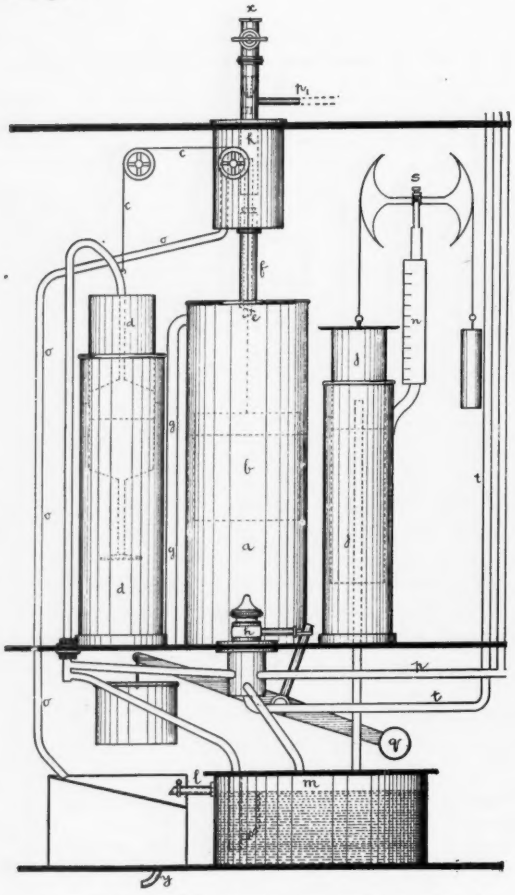


FIG. 1. DIAGRAM OF WORKING PARTS OF SIMMANCE-ABADY CO_2 APPARATUS

This bell, J, then discharges the analyzed gas through the 3-way cock, so that it does not mix or come in contact with the fresh charge of gas, which is dealt with in exactly the same way, the whole operation, as well as the continuous drawing forward of the flue gas, taking place automatically by means of the stream of water.

Projecting from behind the chart disk or drum, Fig. 2, is an arm or lever, which supports the pen at the zero point of the chart. This lever is suspended from the inside of the top of the case, and at its opposite end is a counter-weight hung in the siphon pot, and operated by the weighted float in the pot.

At the proper moment in the cycle, and when the recorder bell has reached the position which indicates on the scale the percentage of CO_2 in the gas, the float in the siphon pot rises and operates the lever, which withdraws its support from the pen arm and allows it to start from zero; the extent of the pen arm travel, and therefore the length of the line on the chart, is limited by the position of a stop hanging from the arm, and touching the disk of the recorder bell. Before the recorder bell discharges, the float in the siphon pot falls, the counter-weight of the pen lever following it, and the pen arm is thus lifted back to zero.

The draft gage consists of 2 connecting metal pots of equal diameter, one closed and the other open at the top, and which contain oil. Connection is made to the

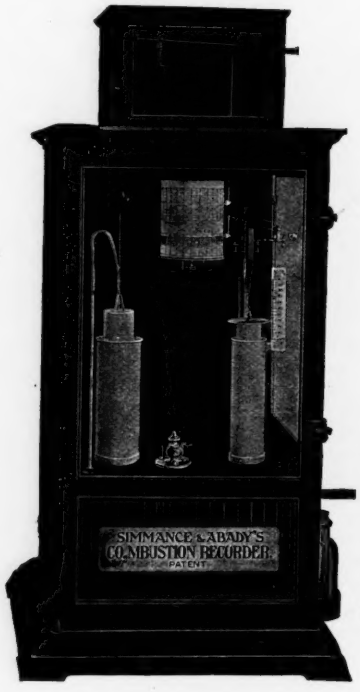


FIG. 2. DRUM TYPE OF CO_2 AND DRAFT RECORDER

closed pot from the flue. A glass float is suspended in the open pot, and connected through a series of levers to the recording pen arm. The vacuum or pressure in the flues causes the oil, and therefore the float, to rise or fall, and the motion is transferred to the open arm, which moves up and down or across the chart while the latter moves with the drum.

With the standard form of apparatus which records CO_2, circular charts are used, but special types are made with drum charts, the drum axis being either vertical or horizontal. The CO_2 and draft type makes both records on the same chart or separate charts, the drum being either vertical or horizontal.

"Sarco" Automatic Combustion (Co_2) Recorder

Sarco Engineering Co., New York

THIS apparatus makes continuous and automatic analysis of the flue gases of boilers, determining and recording on a chart the percentage of carbon dioxide, CO_2, in the flue gas.

Operated by a small stream of water at a head of 4 ft., the recorder traps off samples of gas at regular intervals and brings them into contact with a solution of caustic potash, which absorbs the carbon dioxide. The remaining gas actuates a float which causes a pen to record on a drum the actual percentage of CO_2 in the respective sample.

By means of an aspirator, Q, shown in the cut, gas is drawn through a ¾-in. pipe, which taps the breeching of the boiler, to the inlet pipe, D, of the instrument. Any clean water may be used, only 6 to 8 gal. being required per hour, depending on the speed at which the machine is operated.

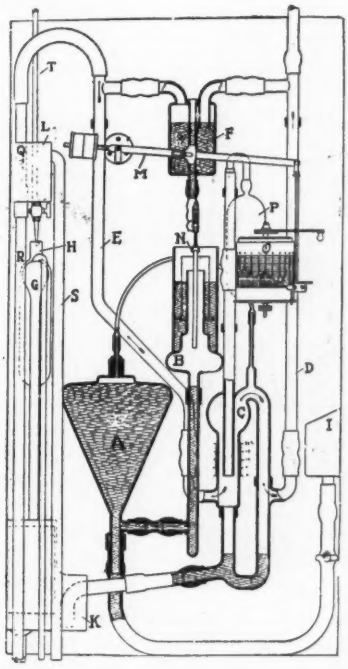
In addition to actuating aspirator, Q, a portion of the water flows from the small tank, L, which serves as a pressure regulator, and is provided with an overflow tube, R. From this tank the water enters tube, H, in a fine stream, the strength of which is adjusted by the cock, according to the number of records that may be desired per hour, and gradually fills the vessel, K, which contains an ebonite float which the water gradually fills through the tube, H, thus compressing the air contained in the vessel, K. This pressure acts upon the mixture of glycerin and water with which K is filled, driving it out into the calibrated tube, C.

While this has been taking place, the aspirator, Q, has been drawing a continuous stream of gas through D, C and E, in the direction indicated by the arrows. When the rising liquid in C has reached the inlet and outlet to this vessel, no further gas can enter the calibrated tubes for the moment, and the aspirator will now draw the gas through the seal, F, and out in the direction of the arrow, for the time being. Before the liquid can close the center tube in C, the gas has to overcome the slight resistance offered by the electric bag, P, and is thereby forced to assume atmospheric pressure.

The moment the liquid has sealed the lower end of this center tube, exactly 100 cu. cent. of flue gas are trapped off to the outer vessel, C, and its companion tube, under atmospheric pressure. As the liquid rises further, the gas is forced through the bent tube and into vessel A, containing a solution of caustic potash which absorbs the CO_2. The remaining gas gradually displaces the potash solution in A, sending it up into vessel B, which has an outer jacket filled with glycerin, supporting a float, N. By means of a thin tube through the center of this float, the air in B is kept at atmospheric pressure. The float is suspended from the pen gear, M, by a silk cord and counterbalanced by the weights, X. The rising liquid in B first pushes a portion of the air therein, out through the center tube in the float, and then raises the latter. This causes the pen lever to swing upwards, carrying the pen with it.

If nothing is absorbed by the potash in A, the calibration of the mechanism is such that the pen will travel to the zero line on the chart, but, should any carbon dioxide be contained in the gas sample, the float action would lift the pen a less distance up the chart, in exact proportion to the amount of CO_2 absorbed. The top of the vertical lines recorded on the chart locate a continuous curve showing the percentage of CO_2 contained in the flue gas.

When the liquid in C has reached the mark on the narrow neck of that tube, the whole of the 100 cu. cent. has been forced on to the surface of the potash, one analysis being thus complete. At this moment the power water, which, simultaneously with rising in tube H has also traveled upward in siphon, G, will have reached the top of this siphon, which then commences to flow. Vessel K is rapidly emptied again, since a much larger quantity of water is disposed of through siphon G than flows in through the cock. When the pressure on this vessel is released, the liquid from C returns into the lower compartment, and float N to its original position. As soon as the liquid in C has fallen



SKETCH OF WORKING PARTS OF "SARCO" CO_2 RECORDER

below the gas inlet and outlet to this vessel, all of the remaining gas is rapidly drawn out through E by the ejector Q.

It will be seen that the gas, when analyzed, leaves the recorder by a set of tubes entirely separate from those through which the samples are obtained, so that there is no possibility of mixing the old with the new.

No attention is required after the apparatus is started, as it operates automatically, necessitating only the changing of charts every 24 hr. and the renewal of the potash solution every 2 or 3 weeks.

Hays Automatic CO_2 and Draft Recorder

G. L. Simonds & Co., Chicago

THIS apparatus consists of 4 separate parts, the analyzer, the recording gage proper, a water pressure regulator and a combined soot filter and condenser.

By means of a system of tubes and a mercury valve, Fig. 1, a definite quantity of gas is trapped off and passed through a vessel containing caustic potash in which the CO_2 of the flue gas is absorbed, the reduction in volume operating so as to show on the chart the exact percentage of CO_2. Water rises and falls in these tubes, and by means of a mercury valve and a water overflow, the levels of all the liquids are automatically corrected at the end of each cycle of analysis.

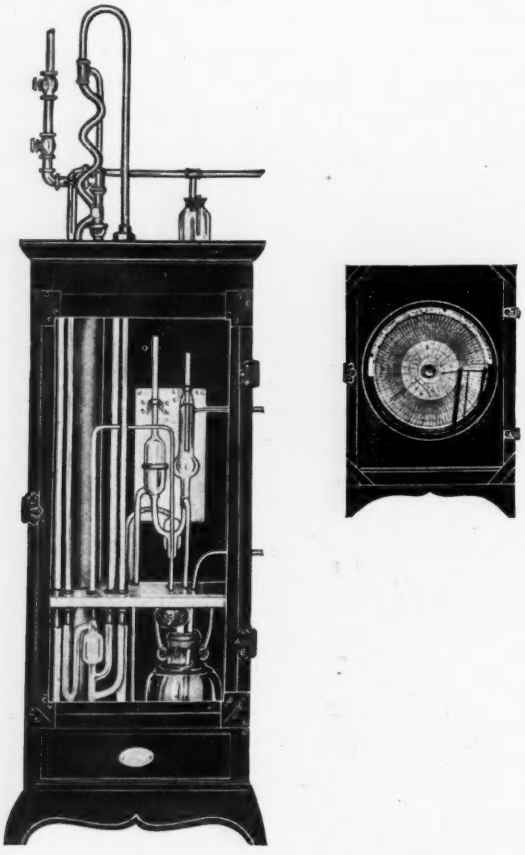


FIG. 1. HAYS AUTOMATIC CO_2 ANALYZER WITH SOOT FILTER AND CONDENSER
FIG. 2. HAYS CO_2 AND DRAFT RECORDER

Since the recording gage, Fig. 2, is separate from the analyzer, and is connected to it with copper tubing, the recorder may be located at a distance, for example, the gage might be located in the engineer's office and the analyzer installed in the boiler room. All that is necessary to put the recorder in operation is to provide the required water and gas connections and connect the analyzer with the recording gage.

Running water furnishes the motive power for the recorder, and, as it is necessary that the apparatus should be supplied with a constant volume of water, so as to maintain a constant speed, a pressure regulator is furnished with the apparatus for this purpose. Water is conducted to the regulator from any convenient source, and is led from the regulator to the analyzer.

Since a uniform temperature is essential to accuracy, because of the expansion and contraction of the gases, the gas measuring and gas absorbing parts are all water jacketed in the same chamber, the water in this chamber being kept in constant circulation to insure uniform temperature.

To remove soot and other foreign matter, the gas is passed through a filter supplied for this purpose, and any water vapor in the gases is condensed before they enter the filter. The gases are taken from the last pass in case of a water-tube boiler, or from the uptake in case of a fire-tube boiler, through a 1-in. pipe which leads direct to the condenser and filter, and from the filter the gases are carried by a ½-in.. pipe to the analyzer.

Caustic potash, which is used for the absorption of CO_2, should be changed about once a month, and the filtering material should be placed in the filter when necessary. Analyses are made at intervals of about 3 min. and the chart upon which both CO_2 and draft in uptake are recorded, covers a period of 24 hr.

Uehling CO_2 Meter

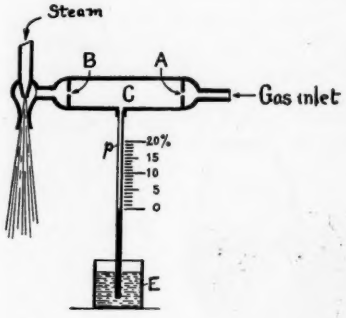
Uehling Sales Co., New York

IN the operation of this apparatus, the principle involved is that of a change of volume producing a change of pressure. Referring to Fig. 1, the gas to be analyzed is drawn through 2 orifices, A and B, by a constant suction produced by an aspirator. A reduction in the gas volume between the orifices, A and B, resulting from the absorption of the CO_2 content, causes a change of pressure in the chamber C, which is transmitted to suitable manometer tubes and recorders calibrated in per cent CO_2.

Essentially the machine proper consists of a cast-iron header and wrought iron cylindrical regulator, on which are mounted and properly assembled, the necessary filters, absorption chambers and the adjusting cocks, as shown in Fig. 2. All connections are brass and copper tubes, which will neither leak nor break. CO_2 is automatically recorded by a gage which operates on the hydrostatic principle, each gage being designed for an 8-in. circular chart reading from 0 to 20 per cent CO_2, and making one revolution in 24 hr., thus giving a continuous record for that period and showing when fires receive attention; when and how often furnace doors were opened, fires broken and cleaned, and the effects of changes in damper regulation and methods of firing. The gage is connected by drawn copper tubing to the CO_2 meters and can be mounted at a distance from them, as, for instance, in the chief engineer's office.

With each unit of the CO_2 meter is included a preliminary filter which is located at or near the boiler. The greater part of the soot and dirt from the gas sample is removed by this filter before reaching the secondary filters on the machine. Owing to the design

and construction, the filter chamber can be conveniently cleaned in a short period without interrupting the operation of the apparatus. CO_2 is absorbed by a dry absorbent carton or cartridge, which may be readily removed and replaced like a dry battery. Owing to the flexibility in the matter of installation, the CO_2 meter



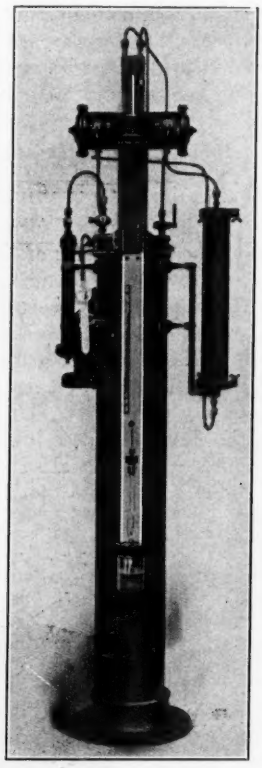


FIG. 1. DIAGRAM SHOWING PRINCIPLE OF OPERATION OF UEHLING CO_2 METER
FIG. 2. UEHLING CO_2 METER

can be located in any clean and convenient part of the plant, while an auxiliary CO_2 indicator can be placed in the boiler room for the guidance of the fireman, and the recording gage mounted in yet another location.

Allen-Moyer Orsat Apparatus

BAUSCH AND LOMB OPTICAL CO., ROCHESTER, N. Y.

WHILE in principle of operation this apparatus does not differ materially from the ordinary form of Orsat, it has some improvements over the old form. Hard rubber capillaries are substituted for glass in the parts easily broken, and the pipe bends are arranged in such a manner as to facilitate their removal for the renewing of solutions. This may be done without danger of spilling the reagents.

There is no leakage from pipettes to dirty the apparatus case and corrode the parts.

As shown in Fig. 1, this apparatus consists of a measuring burette and 3 pipettes, which are joined by rubber connections with pinchcocks to the hard rubber capillary distribution tube. There are also 2 outlets from the tube, each having a pinchcock. There is also a gas bag for each pipette, and a displacement bottle, which is connected to the burette in the usual way. Provision is made for holding the displacement bottle at an elevation when desired.

The water-jacket tube surrounding the burette is made with a white back having a blue stripe so as to facilitate reading the position of the meniscus. The burette is otherwise of the usual Orsat type. The 3 pipettes are composed of an outer tube or mantle which is closed at the top by a rubber stopper and an inner tube, the capillary portion of which passes through the rubber stopper, Fig. 2. The end of the

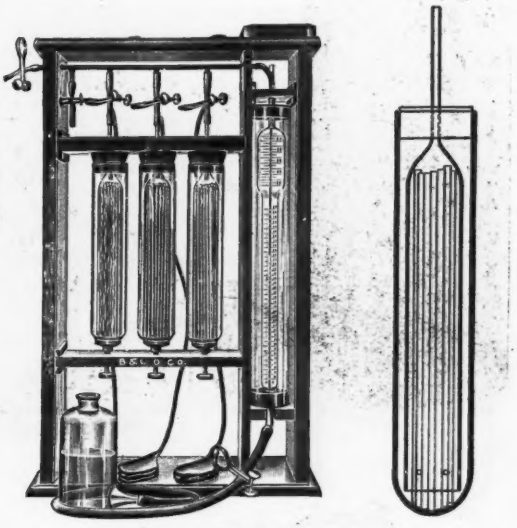


FIG. 1. ALLEN-MOYER ORSAT
FIG. 2. ABSORPTION PIPETTE OF ALLEN-MOYER GAS APPARATUS

inner tube was a number of holes to permit a more rapid passage of the solution from the inner to the outer tube. The inner tube contains a number of small glass tubes to increase the absorption area. It will be seen that the pipette is therefore compact, not liable to breakage and easy to fill or empty. The entire pipette is held in place by means of a hard rubber concave disk supported by a screw, which method tends to keep the rubber stopper tightly in place.

This apparatus is used for the determination of carbon dioxide, oxygen and carbon monoxide in the order given, the usual method being followed in making the analysis.

Wright's Orsat Apparatus

PRECISION INSTRUMENT CO., DETROIT, MICH.

THIS apparatus, Fig. 1, consists of special concentric absorption bulbs or pipettes mounted in a semicircle surrounding the water jacketed burette on a metal stand. The burette is made with an enameled backing down the center of which a colored enameled stripe runs, thus rendering an accurate observation easy and simple. The form of mounting the capillary tube lessens liability to breakage.

For cleaning the gas a filtering tube is provided, and a bottle containing water for drawing in the sample and passing it to and from the burette and the absorption pipette, the latter having rubber bladders fitted to keep the solution free from contact with air.

FIG. 1. WRIGHT'S ORSAT WITH CASE

FIG. 2. WRIGHT'S PORTABLE BOILER TESTER FOR CO_2 AND DRAFT

As the apparatus can be lifted and shaken without damage, rapid and complete absorption is obtained. When not in use it is enclosed in a strong metal cylindrical cover, 5½ in. in diameter by 15 in. high, Fig. 1, the total weight of apparatus charged with solution being only 6 lb. No parts of the apparatus warp and no part of the instrument is subject to strain. The apparatus is made in several forms with from 1 to 4 absorption bulbs.

To determine the percentages of gases, such as CO_2, O and CO, no departure is made from the usual method.

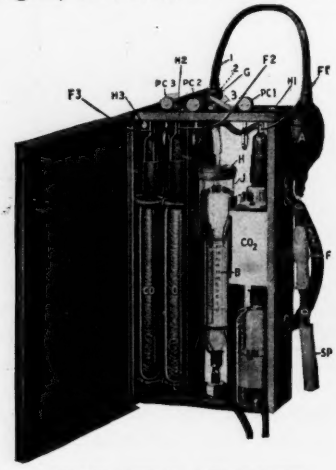
Another form of apparatus, the "boiler tester," Fig. 2, is provided with a draft gage and an arrangement for determining CO_2 only.

Hays Portable Gas Analyzer

G. L. SIMONDS & CO., CHICAGO

IN this improved form of Orsat, used for determining the percentages of CO_2, O and CO in flue gases, are provided a measuring burette, a leveling bottle "L," the absorption vessels for the 3 gases, aspirator "A," soot filter and the necessary cocks, clamps and tubing.

To regulate the temperature of the gas in the burette, which holds 50 cu. cent., the operation is surrounded by a water jacket. The leveling bottle "L" is used for the purpose of passing gas back and forth between the burette and the absorption vessels, each of which contains a reagent, that absorbs one of the gases to be



HAYS ORSAT APPARATUS

measured. By manipulating the leveling bottle, which contains clear water, air may be excluded from the apparatus, and with the aid of the pump, a fresh sample of gas taken in. When the gas has been measured, it is brought into contact with a solution of caustic potash, which absorbs the CO_2, and by measuring the remaining gas the percentage of CO_2 is determined. By passing the remaining gas into an alkaline solution of pyrogallic acid, contained in the second absorption vessel, the oxygen is removed, and in a similar manner the CO is removed by a solution of cuprous-chloride in the next absorption burette. The method is the same as that employed in the ordinary Orsat apparatus, and this order of procedure must be followed, else the results will not be correct. In order to increase the absorbing surface, the absorption tubes are filled with steel fibers, which materially reduce the length of time required for each operation.

Instead of 2 absorption pipes, connected at the bottom, as in the old form of Orsat, these pipettes are made of 2 glass tubes, the smaller one being placed inside the larger. The small tube, which is held inverted, and passes through the stopper in the mouth of the larger tube, has a small capillary tube, fused into its closed end. Since the CO and O solutions are affected by air, both being absorbers of oxygen, an expansion bag is attached to these tubes, thus preventing the liquid from coming into contact with air as they are passed over and back.

The instrument, which is contained in a steel case, is made in a convenient portable size, 3 by 7 by 13 in., and complete with all accessories weighs only 9 lb., making it possible to use the instrument in the boiler room, or wherever desired.

Eddy Smoke Recorder

HAMLER-EDDY SMOKE RECORDER CO., CHICAGO

WITH the aid of an accurate and reliable smoke recorder, it is possible to remedy effectively, the smoke nuisance, as such a device is a check on both the chimney and the fireman.

This instrument, as shown in the illustration, consists of a pump driven by a small motor, a drum, a clock movement, and drying apparatus for removing moisture from the gases.

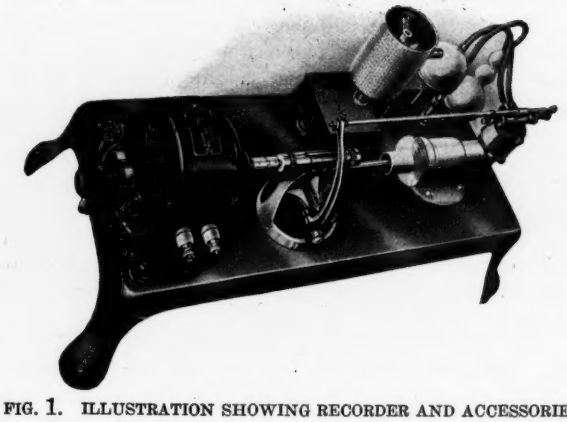


FIG. 1. ILLUSTRATION SHOWING RECORDER AND ACCESSORIES

By means of the pump, which is operated by a 1/12-hp. motor, a jet of smoke or chimney gases is driven through a small orifice against a chart made of porous paper. The soot particles and other coloring matter are driven into the pores, and adhere to the paper, making a permanent record.

As there is more or less moisture in the chimney gases, this must be removed in order to secure a perfect record, which is done without removing the coloring matter.

It is necessary for the chart to be moved by the clock at a rate of speed that properly corresponds to the speed of the pump, otherwise smoke deposits upon the chart will be too light or too dark to represent the exact color of the chimney smoke.

The chart is sectionally ruled in hours and minutes, each chart covering a period in excess of 12 hr. The record indicates, accurately, just when the chimney begins to smoke, its density and its duration. The

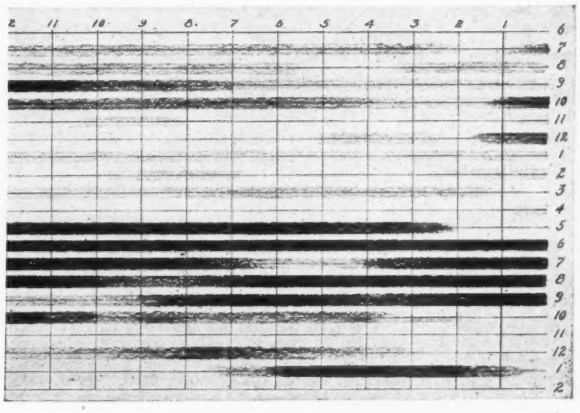


FIG. 2. RECORD OF SMOKE

record is ineffaceable, and if the pipe connections are without valves, the instrument cannot be tampered with.

The entire apparatus, which is 12 by 12 by 25 in. long, and weighs 50 lb., is housed in a glass case to protect it from the dust and draft of the boiler room.

"Sarco" Smoke Recorder

SARCO ENGINEERING CO., NEW YORK

AS its name implies, this instrument gives a record of the smoke density in a chimney or flue throughout the day or night, and thus provides the chief engineer or manager with an accurate record of the actual smoke emitted from the stack. This is valuable data where a smoke ordinance is in effect, and

CHART SHOWING PERIOD OF SMOKING AND DENSITY

complaints from the authorities can always be checked by reference to the charts. The continuous record of performance also gives a valuable check on the work of the firemen.

Smoke, which is caused by gases distilled from the coal not being completely burned in the furnace before coming in contact with the cool surfaces of the boiler, and thus being cooled below the efficient point, varies in density according to the percentage of volatile matter in the coal. Careless stoking will much aggravate the formation of smoke, as heavy firing at long intervals will tend to poor combustion. By scientific and careful firing, lightly and at short intervals, furnace efficiency is increased and a closer approach to smokeless combustion attained.

The "Sarco" recorder consists of an electric lamp on one side of the boiler flue, and on the opposite side, a register with a sensitized white paper dial, fixed on the shaft of a clock. The lamp and dial mechanism are each placed in a sheet-iron cone, at the end away from the flue, and far enough to be out of direct contact with hot gases and to escape grime. Air holes around the lamp admit circulation, to keep it cool and clean. In front of the dial, towards the inside of the chimney, is a light-tight plate, or door, with a narrow slot, which is closed by a tripping device in the clock mechanism, at the end of the record.

When one chart is completed, the person in charge removes the dial and replaces it with a clean sheet. Each dial, which is a disk of photographic paper, is contained in a metal envelope so that no light can reach it except through the slots in the front plate.

When the chimney is clear of smoke, the rays of the electric lamp shine unobstructed through the slot, and when the flue is obscured by unconsumed gases in the flue, the photographic effect is less pronounced. The record varies, therefore, from white when smoke is passing in large masses, to black when the uptake is clear, thus revealing each time that coal is fed to the boiler, or that smoke forms from other cause, and showing exactly the condition of stoking by a glance at the chart. The illustration herewith is of a record taken by the "Sarco" recorder, where there was intermittent smoking throughout the day, and indicates clearly the time of smoking and its duration.

Economical Boiler Room Practice

METHODS AND INSTRUMENTS USED IN MAKING PRACTICAL TESTS, POINTS TO BE WATCHED IN FIRING DIFFERENT TYPES OF FURNACES. BY MARTIN O'CONNOR*

THE object of this article is to give the ordinary operating engineer some practical information along the line of improvement in boiler and furnace efficiency including the uses of flue gas analysis apparatus and the draft gage. The only instruments that need be purchased for this work are an "Orsat" or similar gas analysis outfit costing about $20 and an uptake thermometer or chemical thermometer costing from $2 upward. A draft gage may be constructed by the engineer or any one of the several makes on the market may be purchased. The remainder of the outfit can be made from ordinary pipe fittings and a few pieces of pipe by the engineer.

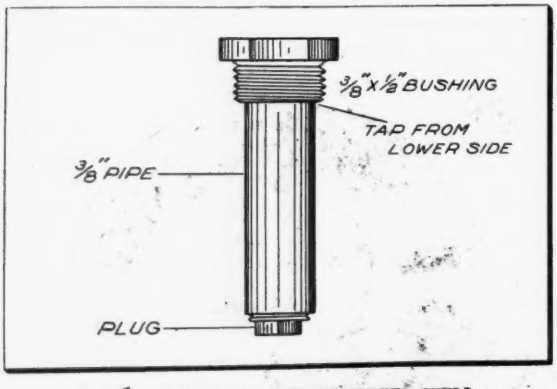


FIG. 1. PRACTICAL THERMOMETER WELL

We should advise making a thorough test of flue gas conditions, uptake temperatures and draft readings, making a record of these findings under the present conditions; then the engineer will be in a position to know what improvements he has made by changes made later. The flue thermometer should be placed in the uptake or gas passage leading from the boiler to the stack and between the boiler and the damper, but at least 12 in. away from any part of the boiler heating surface. If a chemical thermometer is used, a thermometer well may be made as shown in Fig. 1 of 3/8-in. iron pipe and filled with mercury or cylinder oil and the thermometer placed in this. Some asbestos or hair felt should be placed around the stem to prevent any cooling from the surrounding air.

The opening for the the draft gage can be made in any convenient place in the flue between the boiler and the damper and a small piece of pipe inserted with open end at right angles to the flow of the gases. A gage may be made of glass tubing bent by heating over a gas flame and mounted on a graduated board as shown in Fig. 2. This board can be mounted in a convenient place and a pipe led to it. A more portable gage may be made of a small tube, bent as shown, which is more convenient for carrying about and testing the draft in the different passes and over the fire. The gages will be more satisfactory if filled with kerosene which ordinarily has a specific gravity of 0.8 instead of water, then each 1/8 in. will represent 1/10 in. of water.

To collect samples of the flue gases a 3/8-in. pipe should be extended across the gas passage as close to the boiler as possible and have 1/8-in. holes drilled every 6 in. and the end closed, the holes to face toward the stack to prevent clogging with soot. This pipe should

*Experience of over 13 yr. with hand-fired and stoker-fired return-tubular and water-tube boiler plants has taught Mr. O'Connor the ways to discover their ins and outs and overcome their innate contrariness. Six years were spent as assistant engineer with the Milwaukee Division of the Internation Harvester Co., and the last 7 yr. as Chief Engineer of that plant. Many tests, both partial and complete, of plants of different types, have familiarized him with where and how to look for boiler losses.

lead to the aspirator as shown in Fig. 3 and preferably operated with steam or compressed air to draw a continuous stream of gases from the flue. The aspirator can be located where it is convenient to set up the analysis apparatus.

Method of Testing

Readings of the uptake thermometer should be taken and recorded every 15 min. during the run and the average obtained by dividing the sum of all the readings by their number. Flue temperatures ordinarily run between 500 and 600 deg. F. If any abnormally high or low temperatures are noted at times, the cause should be looked for and corrected if possible by controlling drafts or changing methods of firing. Then the boiler heating surface should be thoroughly cleaned at the first opportunity and temperature readings taken during a run as before and results noted. Starting the aspirator, a continuous sample of gas can be drawn from the flue. The analyzing apparatus is connected to the tee between the aspirator and the flue, and the instrument is operated to draw a sample of gas slowly into the measuring burette. The first sample should be forced out without analyzing to remove all of the air. Samples should then be taken every 15 min. Analyzing first for CO_2 (carbon dioxide)then for O (oxygen) and lastly for CO (carbon monoxide) providing the instrument is arranged to handle the last 2 mentioned gases. Readings should be recorded and the average obtained as with the flue temperatures.

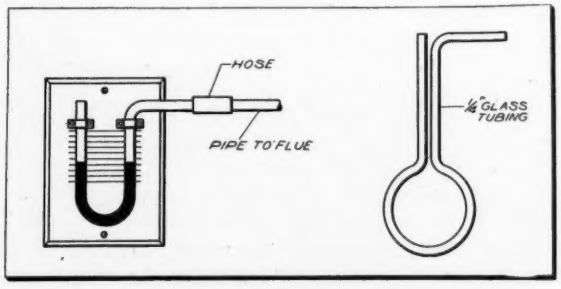


FIG. 2. SIMPLE AND SERVICEABLE DRAFT GAGES

The boiler setting should then be gone over with a torch or lighted candle and any air leaks noted and made tight, using asbestos mortar to close the small cracks and leaks. All ash and flue cleaning doors should be made tight and secure, also taking care that no openings exist through the bridge wall below the grates. Another test should then be made of the flue gases which may show a much higher CO_2.

Tanks for collecting gas samples are sometimes recommended where the tank is filled with water which is allowed to run out during a period of several hours thus drawing in a sample of gas which is supposed to represent the average conditions during the period. This method has not always shown satisfactory results owing to the fact that the water will absorb part of the CO_2, and the tendency of the gases to separate, the CO_2 sinking to the bottom of the tank.

Results to Be Sought

A well handled boiler furnace should show an average of 10 to 12 per cent CO_2, 8 to 10 per cent O and no more than a trace of CO. The above percentages of CO_2 showing 15 to 20 lb. of air per pound of combustible, the theoretical amount being approximately 12 lb. per pound of combustible.

Low CO_2 will indicate leakage of air through the setting, fire too thin or holes in the fire, too strong draft or fire doors open too much. High CO indicates fire too thick, insufficient draft, grate choked with clinkers or too low furnace temperature. The proper thickness of fire depends on the grade of coal used and the strength of the draft varying from 4 in. with slack coal and low draft to 12 or even 18 in. with forced draft and underfeed stokers. Stack draft varies from 0.4 to 1.25 in. of water depending on height of stack and temperature of gases. Forced draft is used as high as 4 or 5 in.

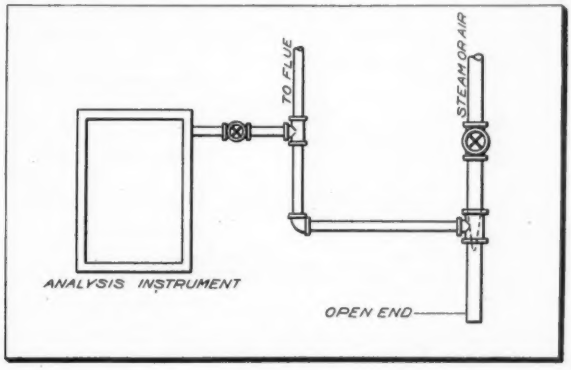


FIG. 3. CONNECTIONS TO GAS ANALYSIS INSTRUMENT

of water in the ash pit. The engineer should experiment with different intensities of draft and positions of stack and ash pit dampers and varying thickness of fire, taking readings of CO_2 and flue temperatures until he finds what method suits his conditions best; always aiming toward high CO_2 and low stack temperatures as long as this does not reduce the capacity or economy of the boiler.

Frequently, the statement is made by engineers that better results are obtained by allowing the combustion chamber under a horizontal tubular boiler to fill with ashes to within a short distance of the boiler shell.

The writer made several evaporation tests on a horizontal boiler with a "dutch oven" furnace and set 7 ft. above the floor line, both with the combustion chamber cleaned down to the floor line and also filled to within 3 ft. of the shell and was unable to detect any difference in flue gases, flue temperatures, capacity or evaporation efficiency when burning bituminous coal hand fired. "Dutch oven" or brick-arch types of furnace are often installed to prevent smoke and increase the efficiency and sometimes do not meet expectations unless carefully fired. The principal reason for this is that the freshly fired coal ignites quickly from the heat of the arch above as well as from the fire below and if not fired light and carefully does not get sufficient air immediately after firing, which causes the produc-

tion of CO and black smoke. In this style of furnace, where hand fired, some arrangement to admit air above the fire for a short time after firing, works very well.

Some Firing Pointers

The mistake is often made of allowing the fire to burn too low before cleaning, especially with forced draft, to prevent loss of unburned coal this results in low CO_2 for some time before cleaning, and causes a much greater loss than the small amount of coal that may be lost, if the fire is cleaned sooner.

Care should be taken with hand firing to keep the corners of the grate surface filled, with the inclined great type of stokers to keep the coal feed uniformly along the grate, and with the chain grate the coal feed and draft should be adjusted to prevent fire from being burned too low before reaching the rear of the grate, and to prevent live coal from being carried over to the ash pit. Ash pits should be cleaned often to allow free access of air to the fire and to prevent burning of the grates.

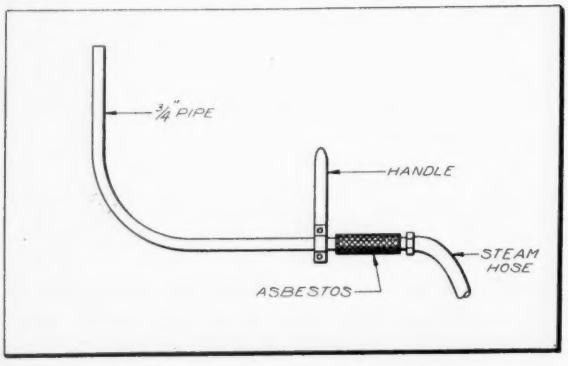


FIG. 4. DEVICE USED FOR CLEANING SPACES IN WATER-TUBE BOILERS

Most types of mechanical stokers will require less repairs if the air supply is controlled by the ash pit dampers and the stack damper kept open as much as possible. All dampers located in stacks of air supply ducts should be made tight on their operating shafts and the operating levers outside should show the position of the damper at all times. Much trouble has been caused by inattention to this important matter. Boilers located near the end of a long flue farthest from the stack always show less draft and require a greater damper opening and sometimes a thinner fire. Use the draft gage in this case to find best setting of the dampers on all the boilers connected to this flue and try to secure a uniform draft on each one.

Dampers on idle boilers leading to the same stack with those in service should be kept closed unless it is necessary to coal a boiler quickly.

The draft gage should be used to test the draft in the uptake, over the fire, in each gas pass in a water-tube and, in the case of forced draft, the air pressure in the ash pit. Readings should be taken and recorded when all the gas passages are clean and boiler operating at its best efficiency as shown by gas analysis and evaporative tests and an effort made to maintain those conditions. An increase in the draft over the fire (the stack draft remaining the same) will indicate a thicker fire, grates clinkered or a reduced supply of air under the grates. A decrease of draft over the fire will indicate a thinner fire, an increased supply of air under the grates or a choking of the gas passages between the fire and the stack.

With the water-tube boilers broken baffle walls will show an increase of draft over the fire. The spaces between the tubes over the fire in horizontal water-tube boilers, when burning same grades of coal and especially with forced draft, soon become filled with fused ashes which will cause a decreased draft over the fire. Those accumulations can best be removed after the fire is cleaned and before a fresh fire is put in by using a curved pipe, as shown in Fig. 4, attached to a steam hose and manipulated through the furnace doors to blow steam upward between the tubes. Any clinker remaining should be thoroughly removed at times of boiler cleaning.

Soot should be blown off the tubes often with steam or compressed air, with devices best suited to the type of boiler used. Some devices now on the market for this purpose do good work with very little labor or discomfort for the fireman. And, finally, frequent evaporative tests should be made as a check on coal and operating conditions. The method for making these tests has often been fully described and need not be taken up in this article.

Draft Gages

Relative Amounts of Air For Combustion Indicated and Relative Pressures of Gases Determined

Owing to its immediate effect upon combustion, draft may properly be considered a most important factor in boiler-room economy and should be carefully determined in order to accomplish the best results. The small pressure differences existing between the atmosphere and boiler furnace, flue or stack, and between the various points in the gas passages, require for their measurement, more accurate and sensitive gases than are used for most other purposes.

Draft gages measure static pressure or difference of pressure, and are of the following types: The diaphragm construction, which indicates or records the draft; an ordinary glass U tube manometer filled with water; the float type in which the inside of a float resting on the surface of a liquid, such as glycerin, communicates with the lower pressure, while the surface of the liquid and outside of the float are subjected to the higher pressures, thus forcing the float downward and actuating a pointer or pen; and an inclined tube, which may be considered a form of U tube manometer, in which the distance moved by the surface of the liquid in the tube is greater than the vertical change of level. There is also a type which combines the U tube and inclined tube, thus covering a long range.

For accuracy and sensitiveness, as in boiler tests, the inclined tube is especially adapted as it shows minute variations. This type of instrument consists of the inclined tube with an enlarged chamber at its lower end, a scale usually graduated to read in 0.01 in. of water, and a light metal frame or case to which is attached a small leveling glass.

To be accurate, it is essential that the bores of both the inclined tube and enlarged chamber be uniform, that is, the ratio of their internal areas must remain constant throughout the ranges traveled by the liquid.

Special mineral oil is best for the liquid, as it has less capillarity, is lighter, permitting a wider range, and is less volatile than water. The inclination of the tube is ordinarily about 1 to 10, and is so adjusted that the air bubbles in the level stand central between the 2 lines when the indicating liquid is poured into the chamber of the glass to zero on the scale, from which point all readings are taken.

Blonck Boiler Efficiency Meter

W. A. Blonck & Co., Chicago

WHEN properly adjusted, this instrument serves as a reliable guide for a fireman to follow, as it indicates instantaneous changes not only in the furnace, but in the steaming capacity of the boiler. By referring to Fig. 1, it will be seen that this meter is a combination of 2 sensitive draft gages, each of which is provided with a sliding scale marked as shown. The lower gage, which is filled with red oil and connected between the atmosphere and furnace, indicates the relative pressure of air entering the furnace, or the resistance of the fuel bed, while the upper gage, which is filled with blue oil and is connected between the furnace and breeching ahead of the damper, furnishes a relative measure of the quantity of gases passing through the combustion space. The sliding scales are adjusted to indicate the draft readings that exist under the best and most efficient operating conditions for the given boiler.

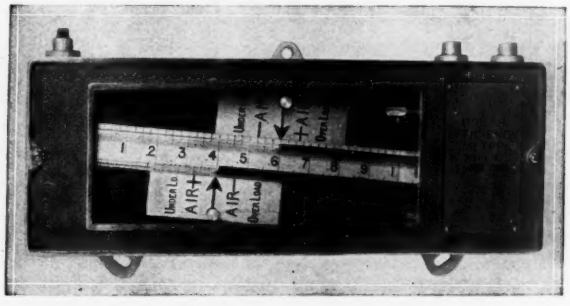


FIG. 1. BLONCK BOILER EFFICIENCY METER

It is the function of a draft gage to indicate the difference in static pressure, and if there were no resistance to the air in passing through the ashpit door, grate and fuel bed, the pressure in the furnace would be practically the same as the atmosphere, showing a zero reading on a gage connecting them. Since these do offer resistance, the draft reading for the passage of a given amount of air will increase with the resistance of the grates and fuel bed. Thus, a high reading of draft would indicate that the fuel bed offers too much resistance and that too little air is passing for complete combustion, and an analysis in this case, would show CO due to lack of oxygen. On the other hand, if the resistance is reduced by holes developing in the fuel, more air will pass into the furnace and the draft gage will read lower, and although this excess of air may produce complete combustion, it will, at the same time, reduce the temperature, and the percentage of CO_2 in the gases will be low. Between these 2 extremes is the point where just enough air passes through the fuel to cause complete combustion without reducing the temperature of the gases, and for normal operations this gage reading should be maintained.

Referring to the upper gage, showing the difference of pressure between the furnace and damper, it will be found that changes in the amount of air furnished the fuel produce an effect opposite to those of furnace draft. For instance, too much air causes greater resistance through the tubes and a higher differential gage reading, while too little air passing offers little resistance and a low gage reading. As in the other case, there is, for normal operation, a medium gage reading which should be maintained.

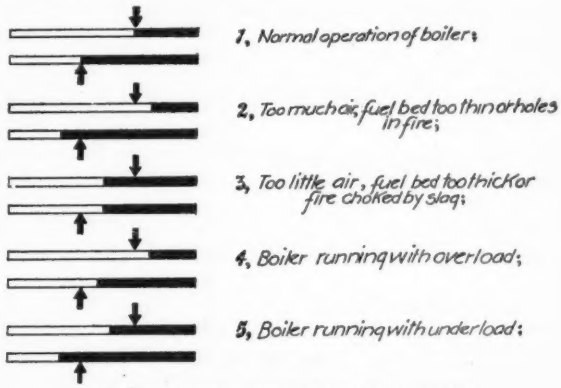

1, Normal operation of boiler;
2, Too much air; fuel bed too thin or holes in fire;
3, Too little air, fuel bed too thick or fire choked by slag;
4, Boiler running with overload;
5, Boiler running with underload;

FIG. 2. DIAGRAM OF BOILER EFFICIENCY METER AND ITS PRINCIPAL INDICATIONS

When a load greater than normal is carried by the boilers, it is necessary to carry a thicker fire, which requires more air for complete combustion. The lower gage, under these conditions, will show a higher reading, and since more gases have to pass through the tubes, the upper gage will also show a higher reading than for a normal load. For a light load, or underload, the effect will be the reverse—that is, both gages will show a lower reading, since less air passes through the fuel bed and, consequently, a smaller quantity of gases through the tubes, or combustion space.

By placing the gages together, the relation between the readings can easily be observed, and a slight change in the operation of the boiler can instantly be noticed, making it possible to restore normal conditions before serious waste can take place. The 5 positions shown in Fig. 2 are those most commonly noted, though others, such as dirty flues or a fallen baffle, are just as readily and quickly shown by the meter. When installed on boilers in batteries, the meter is of further value in keeping the boilers evenly loaded.

Adjustment of the instrument to the most efficient operation should take place while the boiler runs with a steaming capacity equivalent to the longest period of average load, and the most economical results will be obtained when the following 3 conditions take place simultaneously:

A. White fire with fully covered grate, giving high CO_2 in flue gases. B. Low draft over the fire, or low red gage. C. Large pressure drop between fire and damper, showing maximum amount of combustion gases, or high blue gage.

In order to prove the adjustments, a large number of tests were made, which show conclusively that the meter indicates furnace conditions, as well as the load variation.

While it does not give absolute values of CO_2 or rate of steaming, the readings do give the relation to normal operation, and, being instantaneous, the readings are a definite guide, telling the fireman what has taken place in the furnace, when to fire, when the grate is clogged with clinkers, when holes have developed in the fuel bed, and many other detrimental conditions which can be remedied, if known to exist.

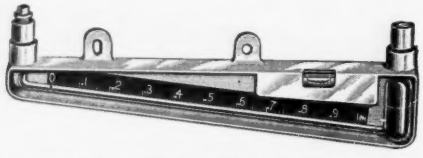
In addition to the indicating instrument, a recording device may be used, which traces the graphic relation at every instant between furnace resistance and boiler resistance. With the indicating instrument mounted on the boiler front and a recorder under lock and key in the engineer's office, there is no chance for deception in the actual handling of the furnaces.

Ellison Differential Draft Gage

LEWIS M. ELLISON, CHICAGO

THIS gage consists of an aluminum casting, a gage glass, a level glass, and a scale. The gage glass is an inclined tube of uniform bore, having at the lower end an enlarged chamber to hold the liquid. The gage, as shown, is for a range of 1 in. of head, and, as the scale is 10 in. long with 10 divisions per inch, it is possible to observe slight variations in draft.

The expanded end of the indicating tube is connected by means of a short nipple and rubber tubing to a pipe of suitable length, which may be inserted in the wall of the boiler or stack where the draft reading may be desired. The difference or drop in pressure between any



ELLISON DIFFERENTIAL DRAFT GAGE

2 points in the furnace or gas passages, may be found by connecting the ends of the gage to those points.

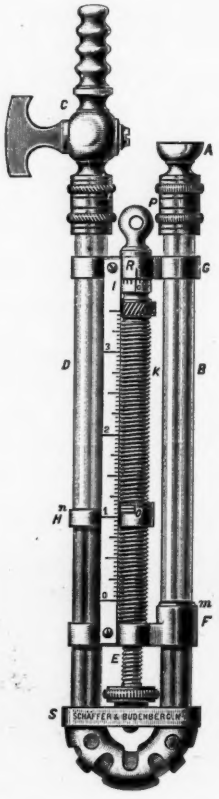
The liquid commonly used in this type of gage is mineral oil, having a specific gravity of about 0.834. This is preferable to water because its capillary attraction is constant, self-correcting, and it is not so volatile. To compensate for the difference in specific gravity and indicate the equivalent head of water on the scale direct, comprising the fall in the indicating tube and the rise in the chamber, the gages are standardized for a correspondingly higher oil head, necessitating no corrections.

Carpenter's Draft Gage

SCHAEFFER AND BUDENBERG MFG. CO., BROOKLYN, N. Y.

THIS instrument was designed by Prof. R. C. Carpenter, and is intended for the purpose of obtaining minute measurement of draft in boiler furnace, chimneys, etc. The gage is fitted with a micrometer attachment, making it possible to take readings to 0.001 in. of water column.

As shown in the accompanying cut, this gage consists of the U glass tube, BD, with air cock, C, for hose connection, cup A, guides G and F, vertical scale I which is divided into inch, ½, ¼ and 1/20 in., screw K for adjusting index pointer O and having 20 threads to the



CARPENTER'S DRAFT GAGE

inch; the index wheel is divided into 25 parts, and the whole combination is raised and lowered by screw E; S serves as a protection for glass tube and bearing for E.

To operate this gage the glass tube is filled with water to about ⅓ its height, one end of a flexible rubber tube being then connected to cock C, and the other end inserted into the chimney flue. B is then opened to the atmosphere and D is in communication with the chimney flue. There will now be a difference of water level in tubes B and D. Adjust m so that it will be tangent to the bottom of the meniscus by screw E, and m by means of screw K. If desirable, cock C can be closed and the difference of water level maintained and taken to some convenient place to read.

Efficiency Testing With the Steam Engine Indicator

ANALYSIS OF HEAT LOSSES FROM THE BOILER TO THE CONDENSER. BY EDWARD M. PIERCE*

ALMOST 35 yr. ago, when as a boy of 14 I began my career about steam machinery, one of the first things which took and held my attention was the shining nickel and the delicate parts of the indicator as I saw it in the hands of the Chief Engineer of the plant where I had taken the exalted position of General Errand Boy and Chief Sweeper. It was a proud day for me when I entered an engine room for the first time as a part of the "force" and one that I have never forgotten. Those first weeks were productive of a great and all pervading weariness, but the glory of belonging to the "force" never lost its charm and hasn't to this day—although some of the glamor has departed. I shall never forget the awe with which I first beheld an Indicator when the Chief brought it out and in a casual, matter-of-fact sort of way, proceeded to attach it to one of the engines—just as if he were doing something of the most ordinary importance instead of conducting a sacred rite.

The impression made on me then has never been quite effaced, although the years have brought me a close and intimate knowledge of the instrument; but, it still has for me the same fascination and I regard it with something of the same feeling of awe. I have grown to love the indicator and to admire it more than any other appliance used about a steam plant and believe it is the most important accessory that the engineer has at his command.

In the course of my experience with the instrument, I have come to formulate a line of investigation which, as far as I know, is original and one which has been of considerable value in my own practice. That I never gave it to the profession was due to a feeling of diffidence and an uncertainty as to the value of the results and methods used. The time has come when it seems to me that a discussion of this line of investigation may bring out something of value to the fraternity; therefore, I shall as briefly as possible outline the methods and principles involved. I shall make no attempt in this article to do more than sketch the ideas and methods; space will not allow of a fuller treatment. It may well be that long ago somebody has used the same ideas and if so I wish to make my apologies to him and give him all due credit for his work. I can only say that I have never seen anything in the literature on the subject that even hints at the underlying idea nor have I ever known of anyone's using it in actual work.

ACCOUNTING FOR HEAT UNITS

BRIEFLY STATED, the proposition is this: To account for every heat unit *available* in the entire range of pressure in the plant under consideration and to use the indicator for the purpose of finding these heat units at important points in the pressure system.

To do this it will be desirable to draw a chart which will represent the pressure range and on this chart we shall plot pressures at various points in the system and by the aid of these points be able to determine the losses at any given part of the entire steam system. Let A B, Fig. 1, represent the line of vacuum carried, and C D be laid off above and parallel to it at a distance which shall represent on a convenient scale the maximum boiler pressure carried. Join these lines and on this vertical line points can be determined which will account for all of the pressure generated. It is then a simple matter to translate the pressures into terms of heat units and then into terms of work. The methods of determining the various pressures and the points where the observations are made, are vital factors in the utility of the tests.

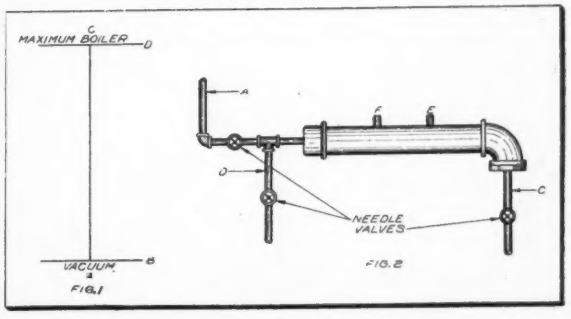


FIG. 1. STEAM PRESSURE RANGE IN POWER PLANT
FIG. 2. PIPING USED FOR CALIBRATING INDICATORS

Having determined the various points on the line AC we can divide the different drops into 2 main divisions, *useful work* and *waste*. Again divide the latter class into 2 divisions, *unavoidable* and *avoidable* waste and the problem is clearly set before us for solution. It will be useless for us to attempt to make any saving in the unavoidable class, so our entire attention can be devoted to the avoidable wastes and results attained without any "lost motion." I propose to sketch the methods of using the indicator so that the above-named divisions can be quickly, accurately and positively made.

CALIBRATION OF INDICATOR

I AM taking it for granted that the reader is familiar with the general use of the indicator and has used it for the purpose of setting valves, determining horsepower, etc., but that he is not what may be called an indicator expert, meaning thereby one who is qualified to adjust, calibrate and apply the instrument in all sorts of places and under all possible conditions. For the benefit of the readers who do not belong to the expert class, I shall give a short method of calibrating the instrument, since it is of vital importance that the indicator

*In the School of Experience, Mr. Pierce has achieved a standing as Past Master. Beginning on a tramp steamer, he worked his way up, in 8 yr., to a 1st class license and had charge of several ships. Then, for 5 yr. he was in the shops of the Richmond Locomotive Co. and the C. & O. R. R., followed by experience in Boston in shops and operating plants. Superintending installation came next in the course, first a hotel plant in Portland, then an office-building plant in Syracuse, which he designed, installed and operated for 7 yr., meantime acting as consulting engineer for an electric railroad. Erecting work with McIntosh & Seymour Co. occupied the next 5 yr., followed by overhauling and redesigning the plant of the Illinois Sewing Machine Co. Designing with Allis-Chalmers Co. and Power & Mining Co., and consulting work has filled his time since then. Special experiment and study on indicator practice, some of it in conjunction with Prof. John E. Sweet, has fitted him particularly to treat of that subject.

be in the very best of condition and the springs as accurate as it is feasible to have them.

Referring to Fig. 2, the pipe A is run directly from the boiler and is used to supply steam to the reservoir, B. The discharge pipe, C, is led to the atmosphere while the pipe D is taken from the steam space of the condenser so that B can be placed in communication with the vacuum. Pipes A, C and D have needle valves in them so that the pressure in B can be kept under perfect control.

Connections E and F on the reservoir are for the indicator and the test gage. If possible to procure, a weighted test gage is to be preferred and in any case the gage *must be accurate,* if the results are to be of any value. Needle valves are used because it is easier to regulate the pressure within very small limits with them than with globe valves. If the apparatus is to be kept for occasional use, as it should be, it is best to cover it with some good pipe covering to prevent radiation.

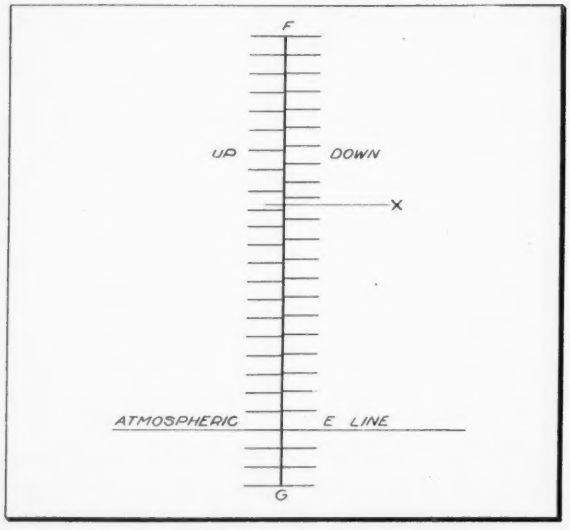


FIG. 3. CARD TAKEN DURING CALIBRATION

The necessary piping having been installed, we are ready to adjust the indicator and calibrate the springs. Take the instrument apart and clean the piston and cylinder carefully with a soft cloth, lightly oil the pencil movement and the piston and reassemble the instrument without a spring. Holding the instrument in the hand, turn it upside down and see if the weight of the piston and pencil movement will cause the pencil point to drop to its limit of motion and again turning the indicator over, see if the pencil drops back to its lowest position. If it does this, it shows that there is no sticking of the piston or pencil motion.

If the pencil will not fall through its range of its own weight, there is some part which is too tight and it must be corrected. An inspection will determine where the trouble lies, when it can be remedied in the proper manner. After this test is satisfactory, take the piston rod between the thumb and finger of one hand and with the other hand try the pencil motion by grasping the end of the pencil lever and feeling whether there be any lost motion in the parts. It will be easy to feel even a small amount of play and, if any exists, it should be eliminated by adjustment. When these tests have been satisfactorily made, and not before, the indicator is in proper working order. The next step is to select the various springs to be used and test them, or as it is called, calibrate them.

This point of calibrating the springs is one that has caused quite a little discussion, but with all due deference to the theoretical sharps, I shall describe a method which is easily within the possibility of the engineer in most engine rooms. It may not be scientifically correct, but the results are as close as the errors of observation in reading the resulting diagrams render needful. It has the merit of being thoroughly practical and easily within the abiiity of anyone.

The springs selected should have capacities such as will easily cover the entire range of pressures which we are about to observe and will give cards of liberal height without in the least straining the spring. For example, suppose that the total range of pressure is from 26 in. of vacuum to 160 lb. gage pressure; at least 3, and better 4, springs should be selected, one of 100 lb., one of 75 lb., another of 20 lb. and the last of 10 lb. These springs will easily cover the entire range and give cards of good height. The capacity of springs of the same scale number varies with the different makes but the capacity as given by the maker should never be exceeded or there will be danger of destroying the elasticity of the spring and entirely ruining it.

Take the indicator piston out, carefully connect the spring, oil the piston slightly and assemble the instrument; connect it to the steam drum, B, Fig. 2, in the usual manner and put on a card. Turn steam on and raise the pressure to the limit of the spring capacity, then lower the pressure, doing this several times until the indicator is thoroughly hot and it is seen that everything is working smoothly.

Try holding the pressure as shown by the gage at some point so that it is perfectly steady, while a line is drawn on the card which will be straight and parallel to the atmospheric line. This is done as a matter of practice so that when the test card is made, no difficulty will be experienced in handling the apparatus.

Everything being in working order, place a new card on the drum and cause the pencil to draw a *vertical* line by holding the drum at about its mid stroke and turning on steam until the limit of capacity is reached. This gives the line E F, Fig. 3, after which the atmospheric line is drawn the whole length of the card. Gradually raise the pressure until the test gage shows exactly 5 lb., then draw a short line *to* the vertical line EF. Raise the pressure another 5 lb. and repeat the operation of drawing a line to E F; continue until the capacity of the spring is reached. Now repeat the operation by dropping the pressure by 5-lb. intervals and draw the lines *from* the vertical line E F instead of to it. The resulting card will look something like Fig. 3. Notice that the 2 sets of lines do not always coincide at their meeting point and this difference is the measure of the error of the spring *plus* the friction of the indicator.

It is not necessary, nor is it always desirable to use 5-lb. intervals between the lines; in the lighter springs,

much closer intervals may be used but it is usually possible to take some small number which is a divisor of the capacity of the spring. For example: The capacity of a certain spring is 36 lb., either 2 or 4-lb. increments may be used and the upper line will be at the exact limit of the spring, so that we have a calibration card which covers the entire range of the spring. It will sometimes occur that springs which show a practically correct card above the atmospheric line, have a considerable error when under vacuum, so that it is desirable to calibrate all of those springs which may have to record pressures below the atmospheric line for vacuum.

Test all of the springs which are to be used and number and designate the cards, so that no mistake can be made about which card belongs to a certain spring. If a spring shows a decided error it will be best to discard it and get a new one, although it is possible to use a faulty spring and use the calibration card as a scale with which to measure the diagrams taken with it.

In making these calibration cards, there is one point which must be carefully watched and that is to see that the pressure is not allowed to exceed that which we wish to record *in the direction we are working*. Thus, if we are about to draw a line on the "up" side of the card which shall represent 25 lb. pressure, care must be taken that steam is not admitted to the reservoir in excess of that pressure, before the line is drawn. If by accident this should happen, it will be necessary to reduce the pressure to a point below 25 lb. and again bring it to the exact point desired. The same is true of the "down" side of the card, pressure must be reduced to the exact point desired and the line dawn, never allowing the pressure to go below the mark and then bringing it up to it, as by so doing you will not get a true record of the spring.

When you examine the calibration cards and compare them with the scale of the springs from which they were taken, you will probably find that the cards are quite different from the scales at some point or points in the range. This difference should be noted and, if it be considerable, it will be best to use the card as a scale rather than the regular scale furnished. In this manner the error of the spring is eliminated to a great extent.

When using a calibration card as a scale, it is usual to lay off a point midway between the up and down lines as at X, Fig. 3, and consider this point as the true scale of that spring. This method is sufficiently accurate for all practical purposes. These calibration cards will not be scientifically correct, due to various causes, the most important of which are the error in the test gage and the inaccuracy of reading it, but this error may be kept very small by care, so that it can safely be ignored. There are other errors, but they are rather for the laboratory expert to take into consideration than the practical man in the engine room. I have no wish to minimize the value of the research work of the laboratory; it is not always possible for the engineer to follow the methods employed there, yet the results he attains are of the highest importance in the successful operation of a steam plant.

Testing Boiler Pressure

Having calibrated the springs we are about to use, made sure of the valve setting on the engine, and corrected all the readily apparent sources of loss in the entire system, we are ready to begin our series of tests, the first of which is to be applied directly to the source of pressure, *the boiler*. We are all familiar with the fact that the steam gage on many a boiler shows quite a fluctuation, if the connection to the gage is left wide open. This shows there is a constantly varying pressure in the boiler and the amount of this variation is what we wish to determine.

Apply the indicator to some convenient point on the boiler, as close to the steam space as we can, but out of the direct current of steam which is being drawn from it. The diagram is taken by drawing out the drum cord by hand, being careful to see that the drum motion is kept steady. The speed with which the drum cord is drawn out will depend to some extent on the speed of the engine and it may be necessary to make a few trials before we get a satisfactory card. This card should show a series of waves, the crests of which are

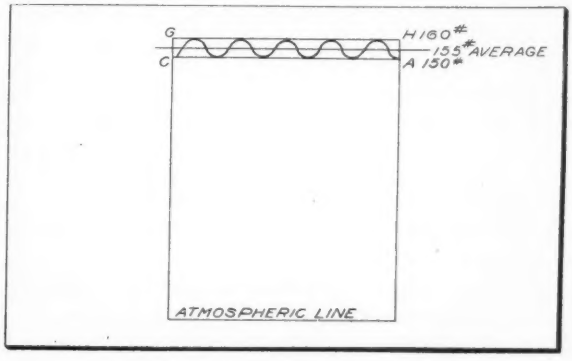


FIG. 4. INDICATOR CARD SHOWING FLUCTUATION IN BOILER PRESSURE

far enough apart to be easily distinguished. Also draw the atmospheric line, then number it and note on it the reading of the steam gage and lay it aside for future consideration.

This diagram is the basis of all the work we are about to do so that the fuller the data given on it, the better. A line, G H, Fig. 4, is drawn by hand so that it just touches the crests of the waves and the line C A is drawn as shown. The distance between these lines measured by the scale of the spring used is the variation in pressure in the boiler. It is apparent that this distance should be as small as it can be made because the true pressure in the boiler is at a point between these lines. If the steam space in the boiler is much too small, there will be considerable fluctuation which results in several evils more or less apparent, such as priming and stresses rhythmically set up in the shell of the boiler. The trouble may be helped to some extent by carrying the water level as low as is consistent with safety but in severe cases it may call for even so radical a measure as the installing of a larger boiler.

Steam Pipe Diagrams

The next diagram is taken from the steam pipe at a point close to the separator but on the *boiler* side of it. This diagram can be made in the same manner as that from the boiler and will look much like it. The parallel lines at the tops and bottoms of the waves are drawn in exactly the same way and the same data is noted on the card. The average height of this diagram will be somewhat less than that taken from the boiler and the difference in their average height is the loss in the steam pipe due to friction, wire drawing, condensation, etc.

The next diagram is taken from the steam pipe but *between the separator and the throttle* and is treated in exactly the same manner as the foregoing. Another card is also taken between the steam chest and the throttle. The difference in the average heights of these cards is the measure of loss between the various points, so that a perfect check is had on the performance of each of the parts of the piping system.

The next diagram is taken from the steam chest of the engine and in this case the indicator cord is hooked onto the reducing motion and the card made in the usual manner. This card is important and should be carefully made; on it should be noted the necessary data so that it can be thoroughly analyzed when we come to consider the entire series of diagrams. Theoretically the card should be a straight line, but this is never attained in practice. The events of admission and cutoff are plainly shown. The difference between pressures when the steam valve is open and when it is closed should be small and the line drawn while the valve is open should not incline towards the atmospheric line.

Naturally this diagram is to be compared with the preceding one rather than with that taken from the boiler. If the drop in pressure is great it denotes one of 2 things, the steam pipe is too small, or there is a serious disarrangement of the valves of the engine. A comparison of the steam pipe diagram and that taken from the high-pressure cylinder will immediately disclose the point at fault. If the line drawn when the steam valve is open inclines toward the atmospheric line, it is proof positive that the steam pipe is too small to supply steam fast enough to fill the space opened by the valve. If the line inclines upward, then the pipe is furnishing steam faster than the demand made upon it.

There are many other things which can be determined from the steam chest diagram, such as the promptness with which the valve closes; it is also possible under certain conditions to determine whether or not the steam valves are leaking, but as there is a much easier method of determining this point, I shall not attempt to explain it. Taken as a whole, this diagram is one of the most interesting of all that we shall have when the series of tests has been completed.

The next diagram is the conventional one taken from the high-pressure cylinder and on it should be noted the gage pressure in both boiler and receiver, also the load as shown by the voltmeter and ammeter so that conditions in the receiver and the low-pressure cylinder shall be as nearly as possible the same when we come to indicate them.

Next point at which the indicator is applied will depend to some extent on how closely we wish to check the various parts of the steam system. It may be applied to the exhaust pipe of the high-pressure cylinder where it leaves the cylinder and again on the same pipe where it enters the receiver, but this will hardly be necessary unless the pipe is long and crooked. Such diagrams would show the loss in the exhaust pipe and also the loss by friction through the exhaust ports and sometimes it would be desirable to know this, but unless it is intended to change the engine radically, these losses may as well be grouped into receiver loss. These diagrams would be made by drawing out the drum cord by hand and would look like the steam pipe diagrams.

The receiver diagram is made by attaching the indicator to the receiver by as short connection as possible and out of the direct current of steam. The card can be drawn in the same way as that from the boiler or the cord can be hooked to the low-pressure reducing motion whichever is more convenient. It will be quite sufficient if the cord is drawn out by hand, as all that is desired is the fluctuation of the steam in the receiver. Remember that the receiver stands to the low-pressure cylinder in place of the boiler, and that it can be considered as such in this series of tests. If the receiver has a reheating coil in service, it will be well to get cards with and without the coil working, as in this way the usefulness of the coil can be determined.

If desired, the next diagram may be taken from the steam pipe of the low-pressure cylinder and the remarks about the exhaust from the high-pressure, apply equally to this point. If taken, the card will show the loss in the steam pipe.

The 2 following diagrams are taken from the low-pressure steam chest and cylinder and nothing need be said of them, except to be careful that the conditions of steam pressure and load are the same as when the corresponding high-pressure cards were made.

If it is thought necessary, diagrams from the low-pressure exhaust pipe can be taken, in the same manner as those from the high-pressure side. Then comes the last card of the series, that from the condenser. It will be advisable to take this card by means of a reducing motion in order to get a check on the action of the steam and to see whether the condenser "takes hold" as it should. In this case it may be necessary to go to considerable trouble in order that the cord to the indicator drum may not be too long. The ingenuity of the engineer will easily overcome any difficulties which may present themselves; no rule can be laid down, as each case will require individual study and treatment.

Correct Use of the Indicator

There are several points in the application of the indicator to which I wish to call attention. These points are by no means new, on the contrary they have been dwelt upon by almost every writer on the indicator; nevertheless, engineers do not seem to realize their importance and continue to attach the instrument in ways that utterly preclude any possibility of accurate results. While I admire and honor the indicator, I must confess that it can be made to lie horribly under certain conditions but I do believe that it is truthful at heart and will tell the facts, if given a fair chance.

The first and most important point is this: *The indicator must always be connected to the point where the pressures are to be observed by a connection which is as short and direct as it is possible to get.* The greater the range of pressure to be observed, the greater the need of short and direct connections for the instrument. The effect of long or crooked piping is serious and becomes so great when working to very close limits, that diagrams taken with long lengths of piping are worthless except for approximately determining the time of certain events. The importance of this fact cannot be too strongly impressed on the mind. Even such short lengths of piping as are required to connect the 2 ends of a cylinder in the usual manner are a source of error and in important tests must be seriously considered.

The next point is almost as important as the foregoing: *Be sure that the cord used is as short as is feasible.* It will pay every engineer who cares for accuracy in his diagrams, to rig up some method of reducing the cord length to its minimum. Several methods are available, such as connecting a ½-in. round rod to the crosshead and having it work through guides bolted to the engine frame and cylinder. This rod carries an arm close to the indicator to which the cord from the reducing wheel is attached. It is not necessary to go into detail on this point, each case will call for careful study, but *reduce the length of the cord to its minimum.*

It seems as if it ought not to be necessary to mention the following rule but I have had experiences within a short time that make me think the point is not as well known as it should be: *The cord, as it is led away from its connection to the crosshead, must be parallel to the piston rod in all directions.* It will not do to have it parallel in one direction only, it must be so in *all* directions. If you will draw a line which shall represent the piston rod and another which represents the cord, the latter being at an angle to the first, you will see by laying off any distance which will represent the stroke, that the angular line will not give a true length of stroke because the angle becomes greater as the crosshead approaches the indicator. Work this out and you will never forget the lesson taught.

Analyzing the Test

We now have a series of diagrams which show the pressures existing at the most important points in the entire system. Sometimes, it will be wise to vary the number of points at which observations are taken, but I have indicated enough to demonstrate the principle involved. Let us take these diagrams and separate them into the 2 main divisions suggested at the beginning of this article. In the first lot we put those which show the performance of useful work and in the other all those remaining. It is self evident that there are only 2 diagrams in the first division, those taken from the engine cylinders because it is there, and there only, that we get any returns in power from the steam generated.

The reason of this division is that the 2 classes of diagrams require different treatment from now on. This will be plain as the laying out of the pressure chart progresses. What we are about to do is to lay off a series of distances on the chart, Fig. 1, which will show at a glance just where every pound of pressure has been absorbed and by a careful study of this layout learn where the serious losses have occurred.

Taking Fig. 1, we remember the scale that we used to construct it and on the same scale we lay off a distance which will represent the maximum fluctuation in the boiler, steam pipe, separator, throttle and steam chest. It is convenient to draw short lines to the left of A C and connect the maximum and minimum pressure lines, as shown by any diagram, by a bracket and either number or label the bracket so that it is easy to distinguish just in what part of the system the fluctuation occurred. At the right of A C draw a short line corresponding to the average pressure as shown by each diagram and give it its proper title.

We have now come to the high-pressure cylinder card and here we lay off the entire range of pressure in the

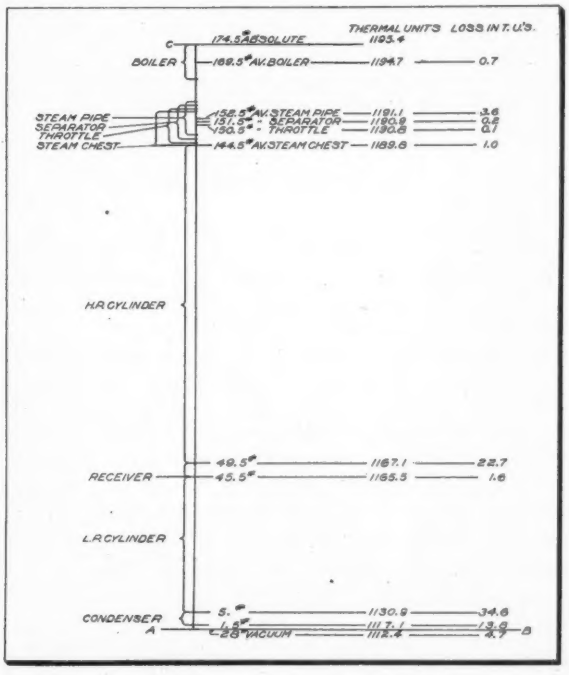


FIG. 5. SEPARATION OF WORK AND LOSSES

cylinder from the time the piston begins its stroke until it is entirely finished. This does not of necessity mean that the back-pressure line is taken as one end of the range. If the terminal pressure at the time the piston reaches the end of the stroke is high, it may be that the range of pressure in the cylinder is considerably less than the range between the steam and exhaust lines. What we desire to get is the actual range of pressure during one forward stroke of the piston irrespective of the back pressure or receiver pressure. We *do not* take the *average* pressure in the cylinder as has been done with the preceding diagrams.

Diagrams taken between the 2 cylinders are treated in the same manner as those first plotted and this likewise applies to the exhaust and condenser diagrams. The low-pressure cylinder diagram is treated the same as the high-pressure.

The result of this work will look somewhat like Fig. 5. It is now possible to see at a glance just where every pound of pressure has been absorbed and this makes it easy to study the results of the tests. We wish to discover just how much loss of heat has taken place outside the cylinders and this is an easy matter, as all that is necessary is to turn to the steam tables and find the heat units in the steam at its maximum pressure, then, subtracting the average number of heat units in the steam as shown by the average pressure at the various points of observation, we have at once the heat lost per pound of steam in any given section of the system. Adding all the losses in heat units which take place outside the cylinders and dividing their sum by the total number of heat units available, we have the total per cent loss.

This does not take into account the latent heat in the steam and we do not need to concern ourselves with it, as what we desire is a practical check on the real amount of heat that is available. There is no utility to us in finding out where the latent heat goes. It is gone and it is utterly impossible for the engine to utilize it, therefore we are not concerned with it.

The Problem Worked Out

Suppose that we work out the problem as presented by Fig. 5 and we shall have a much clearer idea of what I am trying to say. According to the scale, C D is 160 lb. above atmosphere, and this corresponds to the maximum boiler pressure as shown by the indicator diagram. This diagram shows a maximum fluctuation of 10 lb. and we lay off this distance and connect the 2 points with a bracket and write "Boiler" before it. At the right of the line A C we lay off a distance of 5 lb. which is the average pressure in the boiler and write "Av. Boiler" after it. Proceeding in the same manner with the various diagrams until the high-pressure cylinder diagram is reached, we have in succession, boiler, steam pipe, separator, throttle and steam chest.

Now subtract the number of heat units in steam at 155 lb. from those contained in steam at 160 lb. we have from the steam tables, 1195.4 heat units in steam at 174.5 lb. absolute and 1194.7 heat units at 169.5 lb. Subtracting, $1195.4 - 1194.7 = 0.7$ B.t.u. The average pressure in the steam pipe is 138 lb. and the corresponding value in the table is 1191.1; take this from 1194.7 and the remainder is 3.6 heat unit.

These subtractions are continued clear through the whole series of diagrams so that the loss in heat units at any point may be known. When we come to the steam chest diagram, we have a little different method than with the others; we take the average height of the diagram *while the steam valve is open*, and not the average height of the card. In case there is any great difference in the average height of the steam line of the cylinder diagram and that found from the steam chest, it will be due to a valve opening too small which will cause wire drawing and this must be taken into account.

All the foregoing applies to the low-pressure side, but in Fig. 5 I have bunched all the losses in pressure between the 2 cylinders and charged them all to receiver. Adding the heat units absorbed in the 2 cylinders, we have 22.7 in the high pressure and 34.6 in the low, making a total of 57.3 B.t.u. Adding those dissipated outside the cylinders we have a total of 24.7; dividing 24.7 by $(24.7 + 57.3 = 83)$ we get 0.298 of the total heat units available in the steam, which have been lost without having done any useful work. As a matter of fact, quite a large proportion of those which have been absorbed in the cylinders have been wasted through radiation, etc., but that is inevitable. One of the points which will strike us most strongly as we study our chart, is the fact that, as the steam expands, there is a constantly increasing difference in the number of heat units contained in one pound of it. From this we can draw a valuable lesson and that is that it behooves us to see that the condenser and all of its appurtenances are kept in the best possible condition at all times. It is much less of a loss to allow a leak in the steam main than in the exhaust pipe, because a pound difference in the vacuum and in the boiler pressure are not equal in thermal value.

I have made no attempt to show how the heat has been absorbed at any point in the entire system. I have merely tried to show where the losses have taken place and get the proportion that has been dissipated outside those places where it can do useful work.

It may be that from your tests on your own plant you may make some radical changes; in case you do, you will have had reliable data on which to base your calculations and you will know, as surely as 2 and 2 make 4, that you will make certain gains in economy if these changes are made. You have something which you can take to the "boss" and put before him in such form that he can see for himself just what is and what may be.

After you have made all the improvements that are possible for you, then make a complete series of tests and keep this chart on file where it can be looked at occasionally. At intervals, make tests which are to be compared with it and you have a perfect check on the condition of the steam system. If a test falls short of the best that you have ever gotten, something is the matter and it must be looked after. Some of you will say that all this involves too much work and trouble; it is not much work and it is intensely interesting. To any man who is worthy of being called an engineer, the work and trouble will be a joy.

One more word of warning: Use your head when you use the indicator and do not be satisfied with half measure; have everything right, if you wish to get accurate results with it. The indicator is a delicate instrument and because of this fact it does not take much to cause it to err. Make permanent provision for attaching it to the various points desired and the future application of the instrument will be but a matter of minutes where it took hours the first time. When buying indicators, get some first-class, standard make and buy a pair, don't be satisfied with one indicator; because many of the more common uses of it demand 2 indicators in order to get really reliable results. Try the experiment of taking diagrams from your engine with first 1 and then 2 instruments, load and pressure being the same, and you will never be satisfied to get along with one instrument.

There is many a tough problem about the plant which can be solved by aid of the indicator and the very next time you face such a problem, stop and think whether you cannot use your instrument to advantage in working it out. Remember that it will give you an accurate record of pressure at any point where you may attach it and that the stroke of the paper drum can be made to represent time or distance. Keeping these facts in mind, many novel uses of the steam engine indicator will present themselves.

Power Losses

Besides testing as already outlined to find where the heat disappears in its passage from the boiler to the condenser, the indicator will be found of great help in determining the power used by any part of the machinery throughout the plant.

Such tests must usually be made at times when the plant is not running, as the process is one of cumulative effect, starting first with the engine under friction load, then adding belts and shafting up to the point where the machine to be tested is found, and finally taking diagrams with the load on the machine, in which case the difference between successive diagrams shows the amount of the load added.

The method is not one which works well where the load on the machine is small as compared to the other load which the engine is carrying, because slight errors in reaching the larger load may affect the power indicated by the difference as given to the machine by a large percentage.

Care of the indicator has not been taken up in detail, nor has the use of the indicator for setting valves on steam engines, because these 2 subjects have been fully treated in previous issues of Practical Engineer (see December, 1911).

Relation of Indicator to Present-Day Engine Practice

Analyzing Indicator Cards to Find Defects in Operating Conditions. By George H. Wallace*

IT is not the purpose of this article to enter into the details of the indicator or its construction, as there are many reference works which cover these subjects at length, but rather to show as briefly as possible what can be done in the average power plant with the indicator in the way of reducing plant operation to an accurate and scientific basis.

The indicator is an instrument by means of which the pressure in the cylinder of an engine or pump, or other reciprocating device of like nature, can be recorded upon a card, from which can be determined the nature of the work done and the accuracy of the several events which constitute a "cycle" of operation, in addition to the indicated horsepower.

To the operating engineer, the indicator is the same as is the X-ray to the physician. It reveals a field for thought and research, as well as of refinement that is impossible without it.

Owing to the fact that there are many types of engines and other prime movers of like nature, each having a valve mechanism of a different kind, according to the nature of the service and also according to the ideas of the designer, and all aiming to accomplish the same result, it naturally follows that indicator cards show many dissimilarities in recording the events of the stroke which have a common meaning.

Among steam engines we have simple engines with Corliss valves or 4-valve releasing gear, the ordinary 4-valve nonreleasing gear, the 3-valve, which has semi-rotary exhaust valves and a balanced single steam valve, which may also have a riding cutoff valve, in which event, the engine is sometimes referred to as a 4-valve also.

Then there are the high-speed engines with single and double eccentrics, and the ordinary single valve engine, where all the events of the stroke are controlled by one valve, and with all of these different engines, the combination of single, double and even triple ports makes the variety of indicator cards that are considered "good practice," one of almost endless variety.

Every indicator card shows 4 events in the "cycle"; viz., admission, cutoff, release, and compression. These are all shown clearly in Fig. 1, which is taken from the high-pressure side of a cross-compound Corliss engine, the cylinder being 26 by 42.

The steam eccentric was late and the steam rod on the head end was too long, which accounts for the well defined point of admission at A, more so than at A'. Shortening the steam rod so that the point A was the same as A', and then advancing the steam eccentric on the shaft about half an inch, straightened up the admission line so that comprehension and admission blended together.

This card will also be used to note briefly the meaning of the lines which make up an indicator card. Referring to the head-end card, Fig. 1, and beginning at the point A, where admission occurs, and which is the logical place to begin the cycle, the line A E, is the admission line and the line E B, is the steam line, cutoff taking place at the point B.

The expansion line extends from B to C, and during the time the piston is moving between these 2 points, the steam pressure is gradually reducing from what it was at the beginning of the stroke, to a few pounds or even less, until it reaches C, where release takes place. XY is the atmospheric line.

*Our readers already know Mr. Wallace as an entertaining writer of power-plant stories and retailer of sound advice. His right to do this comes from an experience of 21 yr., beginning, after graduation from college, as a boiler-maker's helper, passing to fireman, then to operating engineer, and to rearrangement and installation of plants. For a year he was testing engineer for the Racine Engine Co., then for 6 yr. erecting engineer for the Wisconsin Engine Co., leaving that work to design the power installation and erect it and all factory machinery for the Racine Rubber Co. At present he is in charge of erecting of engines, repairs and changes for the 2 large, new plants of the J. I. Case Threshing Machine Co., which replace 9 plants formerly used.

The exhaust valve remains open from C to D and the line between these 2 points is called the exhaust line. At D the exhaust valve closes and compression begins. The line from D to A is called the compression line. Thus the cycle is completed. The crank-end card marked A′, B′, etc., is similar in every respect.

These lines are identical in name and the location of the 4 events of the valve are the same on all indicator cards taken from any kind of a reciprocating prime mover where steam or compressed air is the expansive agent.

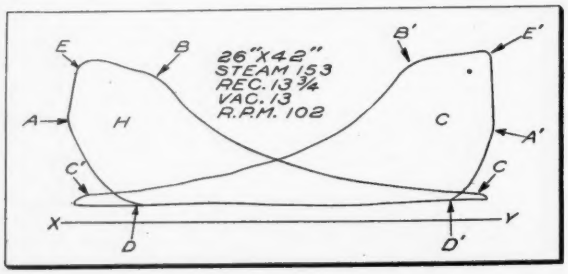


FIG. 1. HIGH-PRESSURE CARD FROM CROSS-COMPOUND CORLISS ENGINE

Where the card is taken from the passive cylinder (as from the air cylinders, in a compressor), while the general outline of the card is similar, the cycle runs backwards, compression being the line CB, discharge the line BE, expansion the line ED and suction the line DC, the only difference being that C should be at the extreme point.

The cards shown in Figs. 2 and 3 are from the low-pressure cylinder, 46 by 42, of the compound, from which Fig. 1 was taken, and are identical as to load and steam pressure, the great apparent difference being due not to any adjustments, but to the disposition of the exhaust steam, Fig. 2 being taken noncondensing and Fig. 3 condensing.

Figure 2—steam, 141 lb.; receiver pressure, 24 lb.; back pressure, 2 lb. gage; speed, 101; scale, 30.

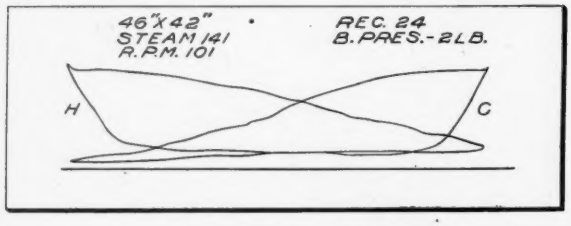


FIG. 2. LOW-PRESSURE CARD FROM ENGINE RUNNING NONCONDENSING

Figure 3—steam, 140; receiver, 9 lb.; vacuum, 12 lb.; speed, 101; scale, 30.

In Fig. 2, compression is prominent, so much so that it rises a trifle above receiver pressure, and in Fig. 3 it is lacking, or practically so; the admission was all right for running noncondensing, it is much too late for condensing.

While the release in Fig. 2 is all that one could desire in everyday practice, as soon as the condenser is thrown on, the release is throttled considerably, the full effect of the vacuum maintained by the condenser not being effective in the cylinder until the piston has traveled about a third of the stroke.

This is due to the relative volume of the steam. While the volume of 1 lb. of steam at 2 lb. pressure is 25 cu. ft., when a vacuum of 12 lb. is produced, it rises to 175 cu. ft., so that at the lower pressure, absolute, there is about 7 times the quantity, or bulk, to make its escape through the exhaust valves in the same time as in Fig. 2.

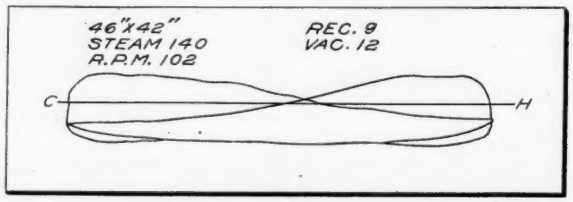


FIG. 3. LOW-PRESSURE CARD FROM ENGINE RUNNING CONDENSING

The card shown in Fig. 4 is taken from a Gates 2-valve automatic engine, with the steam and exhaust valves on opposite sides of the cylinder, the former being functioned by a Rites governor and the latter by a fixed eccentric. Here we have some peculiar features, the load being very unevenly divided between the 2 ends of the cylinder; however, by looking at the events which are controlled by exhaust eccentric, it will be seen that compression is equal at both ends and release, as far as can be judged by the crank-end card, is ideal.

It is clearly shown on the head-end card that admission does not take place until the piston has moved an inch or so on the return stroke and the loop represents a re-expansion of the exhaust steam which has been compressed.

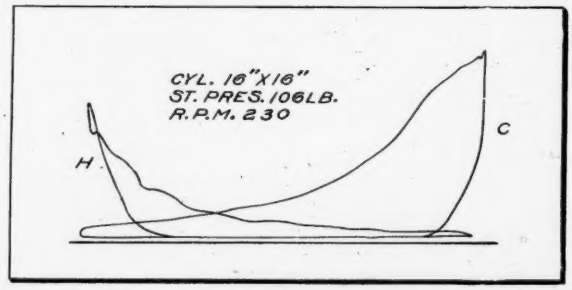


FIG. 4. CARD FROM 2-VALVE AUTOMATIC ENGINE

As the steam eccentric controlled admission and cut-off, adjusting the valve stem for length (indicating meanwhile), restored the valve action to normal conditions, where cards like the crank-end card were taken from both ends under full-load conditions.

The card shown in Fig. 5, while not ideal by any means, is an exceptionally good card as far as valve adjustment is concerned, and also when the operating

conditions are known. The engine was a Fitchburg Brown, 11 by 30; steam, 90 lb. (the limit of the boilers); r.p.m., 97 (original speed, 60); scale, 40.

The engine and valves were in good condition, yet it required several years of persuasion on the part of the engineer to convince the firm that they were losing money by continuing the engine in operation, although practically as good as new.

The terminal pressure is high, about 20 to 25 lb., at which pressure it still has considerable duty remaining, were it possible to utilize it. This pressure is higher than the receiver pressure on many compound engines.

Another common error in indicating is brought out in Fig. 6, where the spring was much too light for the steam pressure. In this instance the engine ran 130 r.p.m. under 140 lb. of steam, while only a 40 spring was used. Some eminent authorities advise that the spring should be half the steam pressure, which in the present instance would mean a 70 spring. It will, however, be found much better to use a spring about ⅔ that

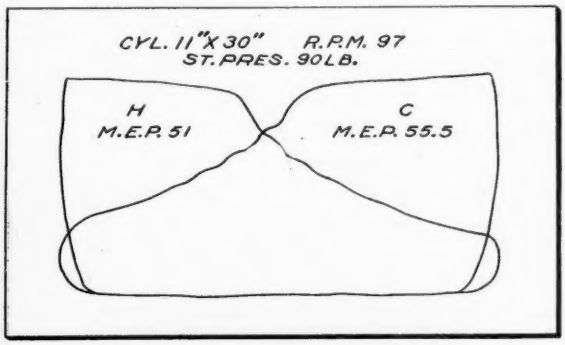


FIG. 5. CARD SHOWING TOO HIGH TERMINAL PRESSURE FOR ECONOMY

of the steam pressure, which in the present instance would have been about a 100 spring. This would have made a card a little less than an inch and a half high, which would have brought out the essential features without strain on the instrument.

The card shown in Fig. 7 illustrates fully the conditions found more frequently than should be. This was taken from a 15 by 36 old box-bed engine that had been in operation for over 50 yr. and, as far as known, had always run as shown.

Apparently there is little lap and the exhaust passages are too small for the rapid exit of the steam. The initial back pressure is about 25 to 30 lb., and although the exhaust pipe, after leaving the engine, was ample, the back pressure in the cylinder was never less than about 7 or 8 lb.

A new Corliss engine, 20 by 36, running 104 r.p.m., was installed and took over all the load with an addition of 3 bearings and 18 ft. of main shafting, and although live steam was used in the process of manufacture at the works, over half the fuel was saved, and one boiler shut down.

Air compressors present some interesting features peculiar to these machines which will be explained briefly by sets of cards from 2 different types of compressors.

The cards shown in Figs. 8, 9, 10 and 11 were taken from a self-contained, cross-compound, 2-stage Ingersoll-Rand compressor having steam cylinders 12 and 20 in. in diameter, air cylinders 18 and 11 in. in diameter, and a common stroke of 16 in.

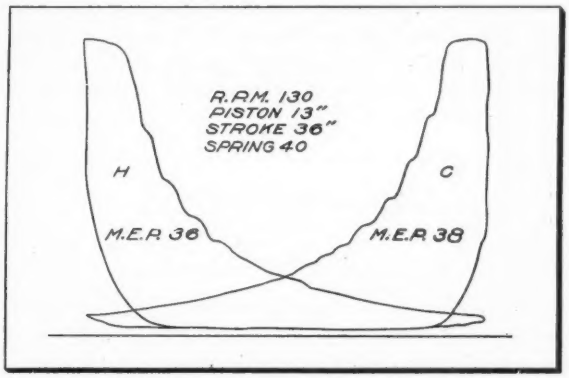


FIG. 6. SPRING TOO LIGHT FOR PRESSURE

The steam cylinders were equipped with a Meyer riding cutoff, both high and low, and a speed and air-controlled throttling governor on the high. The air cylinders had poppet discharge valves and positive suction valves operated by an eccentric. This eccentric with the 2 for the steam valves were cast integral and keyed to the shaft in a predetermined position so that there would be no possibility of disarrangement.

It will be seen, in Figs. 8 and 9, that there is little or no compression on the steam cylinders and that the lead is very late. Yet this is good practice because the

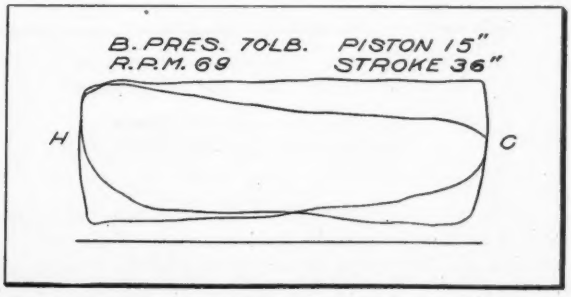


FIG. 7. CARD SHOWING THE LIMIT OF STEAM EXTRAVAGANCE

air cylinders act as a compression cylinder and the re-expansion of the air in the clearance spaces takes the place of early lead.

The irregular discharge line is typical of a poppet valve discharge, and it will be seen that the general features of the head and crank-end cards of both air sets are similar also.

On the high-pressure air card it will be seen that at the beginning of the stroke the re-expansion of the air continues down below the intercooler pressure previous

to the opening of the suction valve, and, owing to the comparatively slow opening of the valve, the air does not enter the cylinder freely until the piston has traveled about a fifth of the stroke. Yet, under the existing conditions, it could not be improved.

The cards shown in Figs. 12, 13, 14 and 15, were taken from a Nordberg cross-compound Corliss driven 2-stage, air compressor, having steam cylinders 18 and 34 in. in diameter, air cylinders 18 and 30 in. and a common stroke of 42 in.

The low-pressure steam cylinder had a single eccentric, with a hand adjustable cutoff, while the high-pressure cylinder had, in addition to the single eccentric operating all 4 valves, the usual cutoff eccentric peculiar to these engines.

Since the air cylinders take care of the compression, it is possible to retard the low-pressure steam eccentric slightly and by reducing the exhaust lap, to line and line, a comparatively free exhaust is secured with a low volume.

The air discharge valves of the second stage have auxiliary poppet valves arranged in the body of the valve, which act as a relief in case of possible disarrangement, and also to permit the passage of all of the air at the end of the stroke when the main valves are closing as is shown near the end of the discharge line in Fig. 14.

The first stage air card, Fig. 15, is so nearly perfect that no comment is necessary.

One day while this compressor was operating in the usual good manner, it suddenly started a series of

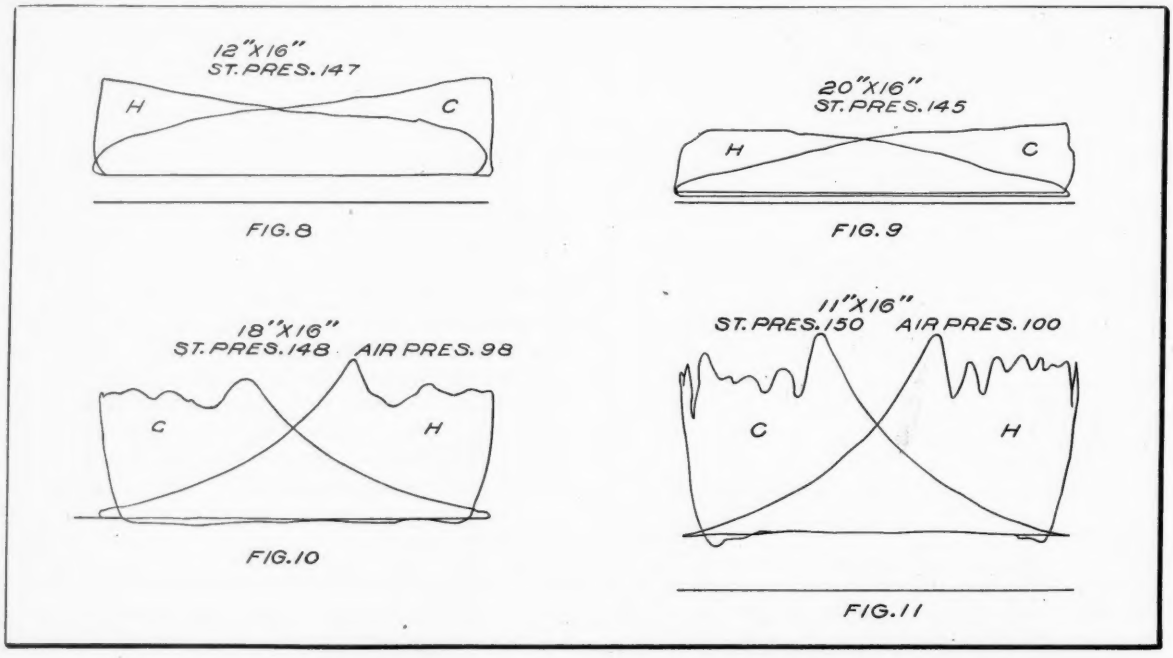


FIG. 8. CARD FROM HIGH-PRESSURE STEAM CYLINDER OF AN AIR COMPRESSOR

FIG. 9. LOW-PRESSURE STEAM CARD FROM AN AIR COMPRESSOR

FIG. 10. CARD FROM FIRST STAGE CYLINDER OF AIR COMPRESSOR

FIG. 11. CARD SHOWING PRESSURE DURING SECOND STAGE OF AIR COMPRESSION

The air cylinders had semi-rotary positive driven valves and each cylinder had a separate eccentric for suction and discharge valves, making really 7 eccentrics on the engine. The engine was running condensing with initial pressure of 145 lb.; receiver pressure 15 lb.; vacuum, 26.5 in.; air pressure, about 100 lb., with 21.5 lb. in the intercooler.

The speed was controlled by a Nordberg governor, which was adjustable over a considerable range with absolute control wherever set for maximum, while the air pressure controlled the minimum speed, as this depended upon the demand for air.

These steam cards are practically ideal, especially on the high-pressure steam cylinder, the compression being low, dependence being placed on the air cylinders to supply the necessary cushion at the end of the stroke.

unusual actions that were finally traced in a general way to the second stage air cylinder.

Upon applying the indicator the card shown in Fig. 16 was secured, which does not much resemble that shown in Fig. 14, which was taken but a short time previously. The result of the investigation was a twisted valve stem on the crank end suction and also on the head end discharge and, to make matters a little worse, a slipped discharge eccentric.

Returning the eccentric to the marks was easily done and the stems were turned over and new keyways cut which kept the machine in operation until new stems were made.

Here was a place where it would have been folly to try any experiments with the valve gear, for had this been done without some knowledge of what had really

happened, the valve gear would have been so distorted that it would have been almost impossible to restore it to normal conditions without considerable delay.

In indicating, while much depends on the manner in which the card is taken from the engine, yet the most important thing is to be able to read the card properly, and then to decide what steps are necessary to secure the desired results, depending on the design of the engine.

FIG. 16. SECOND STAGE CARD, SHOWING EFFECTS OF DERANGEMENTS

With a simple high-speed shaft-governed engine, the valve is designed at best as a happy medium which will work as well as possible under the conditions and the eccentric being fixed to the shaft with the wheel, and the lap determined and fixed by the maker, all that can be done by the engineer is to adjust the valve travel as equally as possible between the 2 ends of the cylinder.

With the Corliss valve gear, or the nonreleasing gear, these little refinements can be carried out more fully, inasmuch as the eccentric is usually fixed by set screws only (unless the steam eccentric on nonreleasing gear engines be operated by a shaft governor) and 2 eccentrics are common. Add to this the fact that all connections between the valve stems and the wristplate (or other means of operation) are adjustable, and by close study, it is possible to secure refinements that are gratifying to the engineer as well as the owner.

These refinements cannot, however, be secured by rule of thumb. They require study and thought, and a knowledge of both the engine and its possibilities, and of the operating conditions, a knowledge which can be secured only by the indicator.

Engine Indicators

ENGINE INDICATORS SHOW GRAPHICALLY THE PRESSURES OF THE MEDIUMS INVOLVED IN POWER PLANT OPERATION

OF the instruments essential to power plant economy, there is none whose utility is greater than that of the engine indicator. It shows by graphic diagrams the variations in the cylinder of pressure of steam, water, air, gas or whatever the working medium may be.

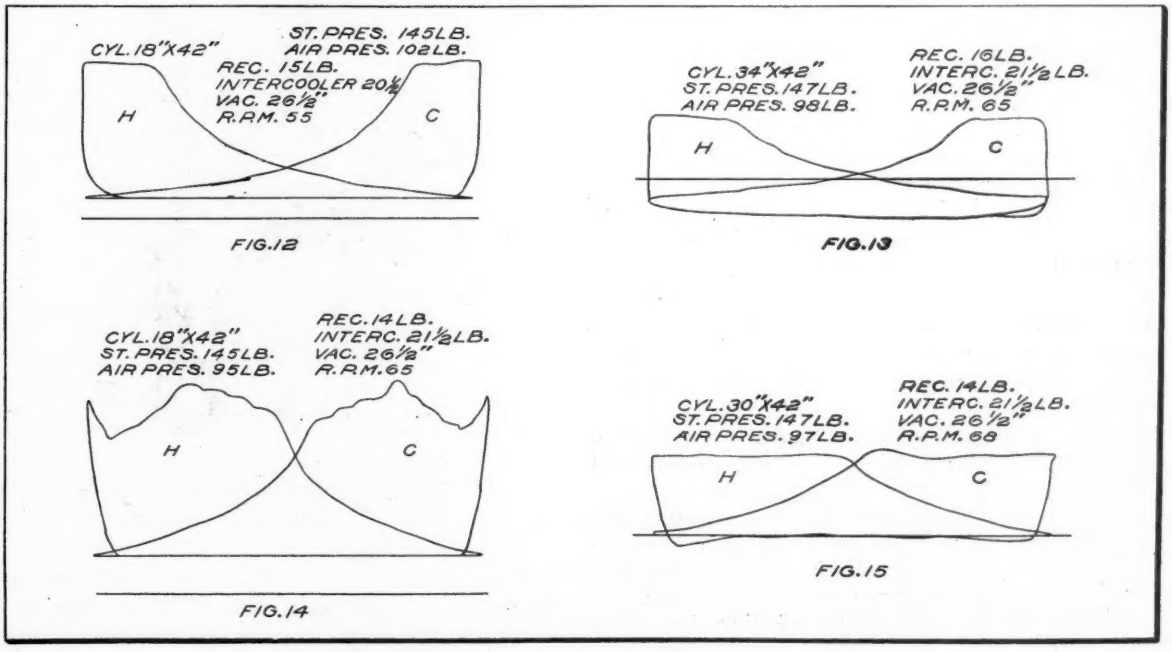


FIG. 12. HIGH-PRESSURE STEAM CARD FROM NORDBERG AIR COMPRESSOR
FIG. 13. LOW-PRESSURE CARD SHOWS ENGINE TO BE RUNNING CONDENSING
FIG. 14. SECOND STAGE AIR CARD FIG. 15. FIRST STAGE AIR CARD

Generally, the instrument is used for checking valve settings, determining the power developed in the cylinder and for approximating the steam consumption of the engine, but its field of usefulness is of greater extent, as

will be seen by the following applications to which it is well adapted: On the steam pipe it will show the pressure drop, due to small or long pipe; on the exhaust pipe it will locate excessive back pressure, whether due to small port openings or exhaust pipe; on the boiler it will register the pulsations due to cutoff valves; it also affords a means of checking up the pressure drop in pipes and of checking pressure gages for correctness. Additional use may be made of the diagrams, which, when transferred to paper ruled logarithmically, furnish a means of determining accurately the steam used, the clearance in the cylinder and the leakage to or from the cylinder.

Pressure on one side of the piston compresses or elongates the indicator spring, one end of which is fixed, the other being free to move with the piston. The movement of the piston is multiplied by the parallel motion, which carries a pencil point that is held against the paper on the drum as the latter rotates back and forth. The drum, which moves in unison with the piston of the engine, is revolved by means of a cord wrapped around its base and connected to the engine crosshead by means of some form of reducing motion, the drum spring holding the cord taut on the return stroke.

Characteristic features of the different types of indicators lie in the parallel motion, pressure springs, and pistons, although the style of drum spring, method of steam jacketing, detent motions, etc., are details that should not be overlooked.

Much depends upon the pencil movement, whose function is to produce at all points of the stroke parallel movement of the pencil, this motion being proportional to the piston travel. The pencil movement should be light but strong and so constructed that the parts will not be subject to wear, which causes lost motion and results in incorrect diagrams.

In most cases the cylinder is removable, being made of brass or bronze, and surrounded by a jacket of the working substance, so as to avoid, as far as possible, radiation, which results in condensation and loss of pressure. Pistons, which are either of bronze composition or steel, are usually made of a thin shell, being as light as is consistent with proper strength. The usual sizes of pistons are 1 sq. in., ½ sq. in. and ¼ sq. in. in area, the ¼ sq. in. area being generally used for high pressures, such as are encountered in gas engines and hydraulic work.

In the design of the indicator, it is necessary that all moving parts be, as far as possible, entirely free from friction and at the same time light in weight, but they should be sufficiently strong to perform their work with a minimum of wear and without affecting their alinement. Lightness of moving parts is also essential to avoid the distorting effect of inertia on the diagram.

Increased use of high pressures, superheated steam, and internal combustion engines have brought about the development of indicators with the spring exposed to the atmosphere, as the inside spring is subject to change in temper if exposed to extreme heat. Nearly all modern indicators are now made in both the inside and outside spring types, the design being changed slightly to accommodate the location of the spring.

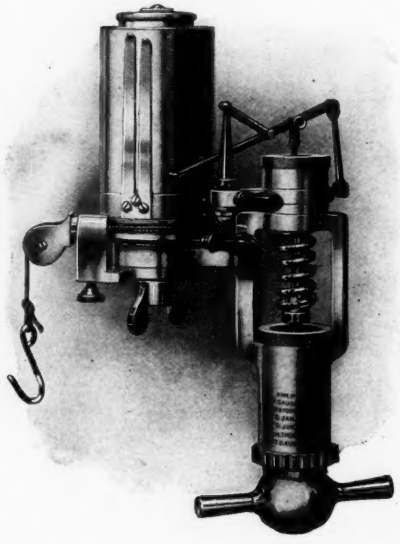
American-Thompson Improved Indicator

AMERICAN STEAM GAUGE & VALVE MFG. CO.

AS implied by the name, the Thompson parallel movement is employed in this indicator, straight line motion of the pencil being secured at all points of the stroke. The construction of the inside and exposed spring types is similar, except in the location of the spring.

In the cut is shown the exposed spring type in which the spring is free from the effects of high temperatures and may be changed while the instrument is hot. The spring, which works under compression, is wound in a single coil from carefully tempered steel wire, the ends of the coil being securely fastened to brass heads tapped to fit the piston rod and the threaded stem on the lower side of the cap, respectively.

No change in the parallel movement is necessary to adapt it to the exposed spring construction, as the spring is located between the cylinder and the pencil motion. The piston rod is only ½ in. longer, which brings the piston and pencil bar close together, avoiding any tendency of the rod to buckle.



THE AMERICAN EXPOSED SPRING INDICATOR WITH IMPROVED DETENT MOTION

Parallel movement of the pencil is secured by a link attached to and governing the lever direct, thus minimizing lost motion. The pencil lever, which has a 3 to 1 ratio, is joined to the piston by means of a connecting rod, the lower end of which forms a socket that rests on the adjustable ball stud at the upper end of the piston stem, thus providing a ball and socket joint and affording a means of taking up lost motion.

Both the piston and cylinder are made of bronze, the piston being grooved for water packing and made as light as is consistent with strength. The pistons for steam engine indicators have an area of ½ sq. in.

In order that any number of cards may be taken without unhooking the indicator cord, the drum is equipped with a detent motion. The atmospheric line requires no adjustment, as all cylinder springs are scaled with allowance for full vacuum.

Tabor Indicator

ASHCROFT MFG. CO., NEW YORK

PARALLEL motion is accomplished in this indicator by means of a stationary guide plate containing a curved slot, Fig. 1, in which there moves a roller bearing fastened to the pencil bar by a small

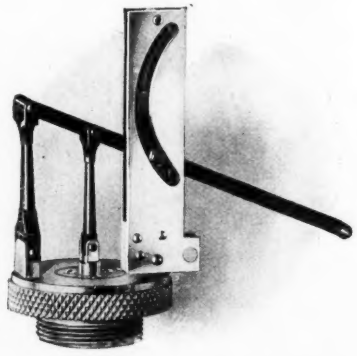


FIG. 1. PARALLEL MOVEMENT OF TABOR INDICATOR

pin. This produces a straight-line motion of the pencil and a constant ratio of pencil movement to piston movement is maintained during every part of the stroke.

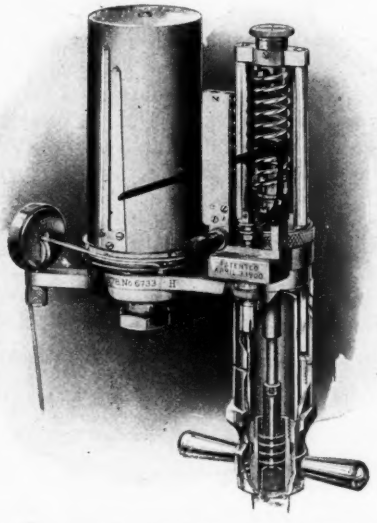


FIG. 2. TABOR OUTSIDE SPRING INDICATOR

Pressure springs used on the Tabor indicator are of the duplex type, made from 2 coils of wire attached exactly opposite to each other on the bases. The purpose of such an arrangement is to give uniform distribution of stress on the spring and keep the piston central in the cylinder, avoiding any tendency to bind in the cylinder. In the type of instrument shown by Fig. 2, the outside spring is used, thus relieving it from the effects of the heat and permitting a quick change of springs. Two sizes of pistons are provided, the ½-in. area for steam and the ¼-in. area, which operates in the upper portion of the cock tube, for hydraulic or gas engine use.

The pistons now used in the Tabor instrument are so designed as to have the effect of 4 short pistons separated by deep grooves. These grooved sections not only aid lubrication but also serve as a place of storage for dirt and foreign substances encountered in the cylinder.

Bachelder Indicator

JOHN S. BUSHNELL & CO., BROOKLYN, N. Y.

CHARACTERISTICS of this instrument, Fig. 1, are the hollow T-shaped case and adjustable flat spring. The cylinder is screwed into the lower end of the case and held by a small set screw, requiring a half turn to permit the cylinder to be unscrewed. The

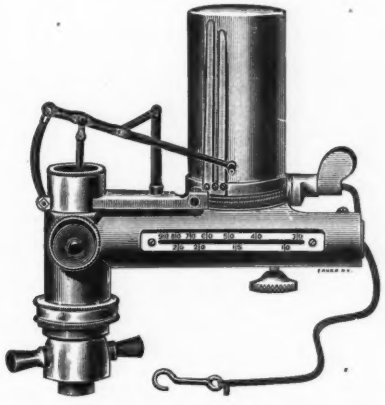


FIG. 1. BACHELDER INDICATOR SHOWING PARALLEL MOTION AND SPRING SCALE

flat spring works in the horizontal body of the case, one end being secured rigidly by means of a taper screw

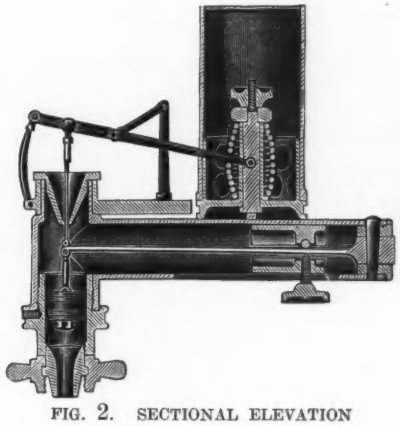


FIG. 2. SECTIONAL ELEVATION

and the other attached to the connecting rod between the piston and pencil lever. To remove the spring it is only necessary to remove the screw connecting it to the piston rod and the one which holds it in the case. So

great is the range of the high-pressure spring that no change is necessary, except when using the instrument on a compound or triple expansion engine. Connection is made to the piston with a ball and socket joint and access can be had to the piston for oiling or removing. by unscrewing the knurled cap on the face of the instrument.

As will be seen from the section, Fig. 2, the flat spring extends through a recess in a split bushing in the upper side of which is inserted a hardened steel pin, against which the spring is held rigidly by a set screw passing up through the lower side of the bushing. By loosening the set screw and sliding the bushing along until the mark on the projecting block is opposite the scale required, it is possible to vary the scale of the spring as desired. The upper scale, marked on the face of the case is for high pressure, while the lower one is for low pressure. With these 2 springs it is possible to indicate over a range of pressures from 10 to 200 lb.

Freedom from lost motion and friction makes the parallel motion entirely accurate. By means of a swivel in the connecting rod near the pencil lever, it is possible to adjust the height of the pencil point as desired. Since downward motion of the spring is the same as upward, a correct diagram is given from the condensing or low-pressure cylinder of a compound engine. These indicators are now fitted with a simple form of detent motion, enabling the operator to change cards without unhooking the indicator cord. It will be noted that this is really an outside spring with the additional advantage of being partly encased so as to protect it from outside variations in temperature. The piston is of the ordinary type, grooved for water packing against leakage.

Crosby New Indicator

CROSBY STEAM GAGE & VALVE CO., BOSTON, MASS.

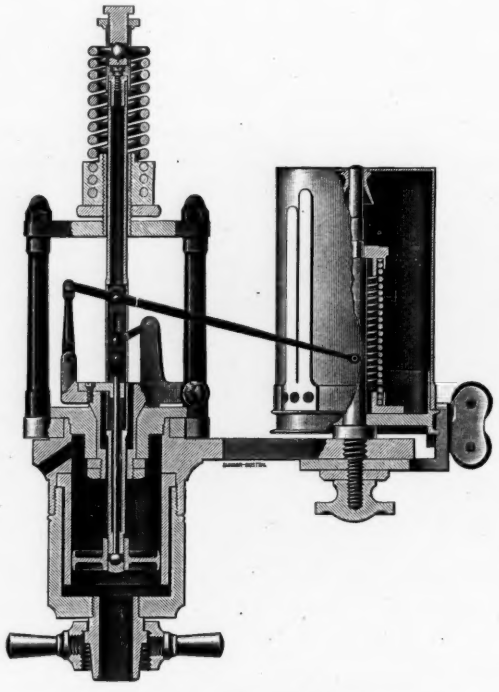
AS illustrated, this indicator is designed for an outside spring, thus removing the error arising from the action of heat on the spring and making the changing of springs an easy matter.

It is to be noted that the piston, which is 1 sq. in. in area, is in form the central zone of a sphere, thus affording great active force with a very light pencil mechanism. It is attached by a rod directly to the upper part of the spring and moves freely, regardless of any eccentricity in the spring. Line contact of the piston with the interior of the cylinder reduces friction to a minimum.

By means of a ball and socket joint, the pencil mechanism is connected with a rod to and directly over the piston. This rod slides through a sleeve attached to the base of the pencil mechanism, and, moving in a vertical line, compels the pencil also to move in a vertical line. Thus, any motion of the piston, due to the movement of the spring which might cause the spring rod to deviate, will not affect the pencil mechanism in its vertical course.

Of unique design and construction is the piston spring, which is made of a single piece of fine spring steel wire, wound from the middle into a double coil, the spiral ends of which are screwed into a brass head having 4 radial wings. Adjustment is made by screwing them into the heads until the proper strength of spring is obtained, when they are firmly fixed. This spring avoids all eccentricity and unnecessary weight, which might produce friction or error in the operation of the instrument.

In addition to the large piston, a smaller piston of ½-sq. in. area is furnished for use with gas engines.



SECTION OF CROSBY OUTSIDE SPRING INDICATOR

By adjusting the pencil the diagram may be located in any desired position on the drum, it being only necessary to loosen the binding nut below the spring, and screw the spring upwards or downwards, carrying with it the entire pencil mechanism. For taking a series of diagrams a special drum is used upon which a roll of paper is wound in such a way that a diagram may be taken for each revolution of the engine.

Improved Robertson-Thompson Indicator

JAMES L. ROBERTSON & SONS, NEW YORK

AS shown by the cut, this instrument has a removable steam jacketed cylinder and is equipped with the Thompson parallel motion. The instrument is of standard size with ½ sq. in. area piston, an additional piston of ¼ sq. in. area being furnished with each instrument for use with gas engines and on high pressures. With this piston, the springs can be used for pressures 4 times greater than those for which they are marked. Thus, a 50-lb. spring can be used for 200 lb. on a ¼ sq. in. piston.

To keep the top side of the piston free from pressure, a swivel elbow is provided, by means of which the steam may be discharged in any direction at the will of the

operator. This prevents the escaped steam from coming in contact with the hand or wetting the cord, causing it to stretch and make a defective diagram.

Pressure springs of a single wire are used, as they are accurate, allow for ample compression and are not apt to buckle. The upper head has 4 wings with holes drilled to receive the coils, final adjustment being made by screwing the coils in or out, after which they are carefully tested, firmly secured and ready for use.

Pistons, which are made of special metals, are provided with the usual water grooves and carefully fitted.

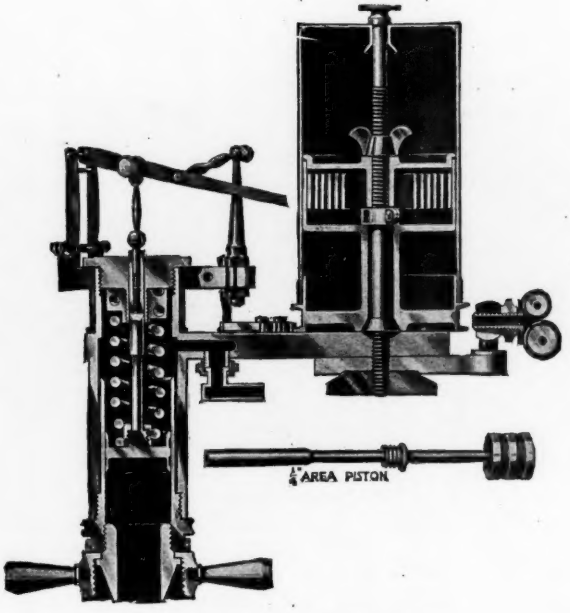


FIG. 1. SECTIONAL ELEVATION OF ROBERTSON-THOMPSON INDICATOR

Each indicator is fitted with a detent or stop motion for the drum, ratchet teeth being cut on the bottom of flange of the drum carrier and a handle provided to engage or disengage the pawl, enabling the operator to stop the drum so as to remove and replace cards without disconnecting the indicator cord.

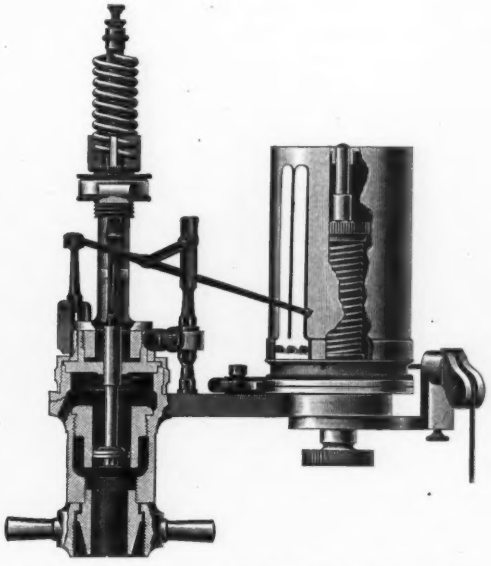
By turning the movement around on the swivel arm and reversing the drum, the indicator can be readily changed from right to left hand, adapting it to any style of engine.

Star Indicator

STAR BRASS MFG. CO., BOSTON, MASS.

IN the illustration is shown a sectional view of the outside spring type of indicator, in which the spring is readily accessible for quick changes when the instrument is hot, and at the same time free from the ill effects of high temperatures. Thompson's parallel movement has been adapted to this construction, insuring straight line motion of the pencil at all points of the stroke.

Since the spring is under tension, tendency of the piston to stick and the possibility of buckling of the piston rod and spring are avoided. The spring is wound into a double coil from a single piece of steel wire, the 2 ends being attached to a bronze head, which is securely screwed down against the framework above the cylinder. At the upper end of the spring there is no metal except a small spherical ball, which is firmly attached to the spring and furnishes a ball and socket joint between the spring and piston.



SECTION OF STAR OUTSIDE SPRING INDICATOR

At the upper end of the piston rod is a slot through which the bead passes and a knurled screw which secures the bead in its bearing. The piston rod is also hollow and is slotted for the pencil bar and connecting link. Adjustment of the height of the atmospheric line is made by turning the knurled washers below the spring.

With the small piston, which has an area of ¼ sq. in. and is very narrow, weight and friction are reduced to a minimum, permitting the use of a light spring, which makes the instrument both sensitive and accurate. Owing to the light construction of the moving parts, the error resulting from inertia is also minimized.

Schaeffer & Budenberg Indicator

SCHAEFFER & BUDENBERG MFG. CO., BROOKLYN, N. Y.

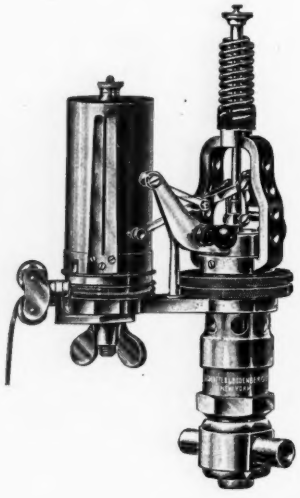
IN the figure is shown the outside spring type of instrument, a construction which not only makes the spring readily accessible and permits of changing it while the indicator is hot, but also leaves the spring cool, thus eliminating any trouble which might result from the effects of high temperatures.

By means of a special arrangement, consisting of a forked pencil bar, the Thompson parallel movement has been adapted to this construction, thus giving the pencil a straight line motion at all times.

In order to reduce inertia to a minimum, the spring, which is wound from a single piece of spring steel wire, has a small steel bead at the top instead of the ordinary brass head. The ends of the coil are fastened to the

wings of a bronze base which is threaded to fit the stem on top of the bridge against which the spring is securely screwed down.

Both the piston and piston rod are made of high grade steel, the piston being partially bored out and the rod made hollow to reduce weight. The upper end of the piston rod is slotted to fit the small bead at the top of the spring, this being held firmly in place by a thumbscrew.



SCHAEFFER & BUDENBERG OUTSIDE SPRING INDICATOR

To protect the springs when subjected to excessive pressures, a shoulder on the piston rod serves as a safety stop limiting the piston travel. For the purpose of facilitating handling while hot, the cylinder cap is provided with a vulcan fiber covering which forms an insulation that always remains cool.

Triumph Indicator

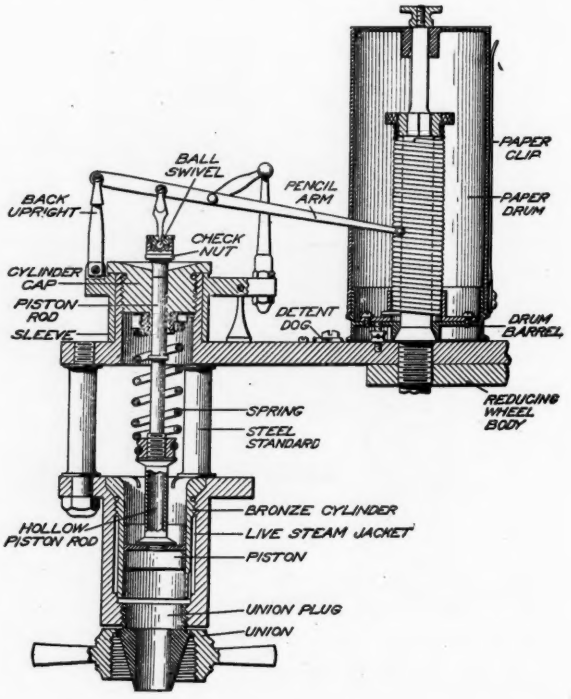
TRILL INDICATOR CO., CORRY, PA.

EITHER the inside or the outside spring construction is used in the Triumph indicator, the advantage of the latter being that the spring is free from the action of high temperatures. The latter type is shown in the figure.

Single springs of 4 coils per inch permit of ample pencil travel with a low unit fiber stress and distortion, the chance for error being slight under such conditions. The moving head at the bottom is a threaded bushing of light weight screwed into the spring, thus reducing inertia. The upper end of the spring is soldered into a head having 4 wings and a threaded central hole which engages with a stem on the lower side of the cylinder cap. The ratio of compression is adjusted by twisting the spring in or out of the milled grooves of the wings.

Ordinarily the piston, which is made from steam bronze having a low coefficient of expansion, has an area of ½ sq. in. Two shallow grooves retain the oil and water, forming a frictionless and steam-tight packing. The piston rod, which is of tool steel, has its lower end threaded into the piston head, the upper end being hollow and tapped to receive the swivel socket. The swivel consists of a ball and socket joint which gives a large wearing surface and also eliminates lost motion between the piston rod and the link connecting it to the pencil bar.

Being of the Thompson type, the pencil movement is made of tool steel and has wide bearings throughout, rendering it strong but light and free from the effects of inertia, which is a common source of trouble. In this design, the piston movement is multiplied 5 times, the pencil motion being parallel at all points of travel.



SECTION SHOWING TRIUMPH OUTSIDE SPRING INDICATOR

By means of the ball and socket swivel, the atmospheric line can be raised or lowered as desired. To prevent overloading the indicator spring, a square shoulder on the piston rod is provided, thus serving as a safety stop when it strikes the cylinder cap. The drum is equipped with a detent motion which makes it possible to change cards without unhooking the indicator cord.

THE KENTUCKY UTILITIES CO., with headquarters in Lexington, Ky., has taken over the electric light plant at Varilla, Ky., which was originally built to serve the various mines of T. J. Asher, who owns a 38,000-acre coal tract near that place. This will be used by the company for the central plant in that district. Electricity will be transmitted at 33,000 volts to the mines of the Bell-Harlan fields, with reserve stations at Middlesboro and Pineville.

LOYALTY IS that quality which urges us to be true to whatever we undertake in life. To be steadfast; true to ourselves and to others.

Design As A Factor In Power Plant Economy

STUDY OF EQUIPMENT BEST ADAPTED TO THE CONDITIONS, ARRANGEMENT OF MACHINERY, SUGGESTIONS ON PIPING. BY R. A. LANGWORTHY*

THIS article is written to call attention to some of the principles of steam power plant design, which are often over-looked by those responsible for the selection and installation of equipment. It is intended primarily to cover plants of moderate size, up to about 2500 hp., such as are required in industrial work and small central station practice. The subject is a broad one and we must therefore treat it in the most general manner.

TYPE OF EQUIPMENT

IN SELECTING the equipment for a new plant, or in recommending changes for one already existing, a careful survey and analysis should be made of all local conditions which will affect the design and operation. A few points to be considered in this connection are: 1. Load. 2. Space available. 3. Future extensions. 4. Transportation facilities. 5. Fuel. 6. Water supply. 7. Location.

A brief explanation of the above mentioned subjects will be given. A proper consideration of such matters, before the plant is built, will inevitably result in lower first cost, reliability and decreased operating expenses.

LOAD

THE LOAD on the plant should be carefully studied, both as to amount and character. The load factor of any power plant or individual unit has a decided effect on the economy. Having determined upon the maximum load, we must fix upon the number, size and type of prime movers. Under ordinary conditions, except in small plants, it is not advisable to concentrate the power in one unit for the following reasons. 1. In case of trouble the whole plant is shut down. 2. At times of light load the unit runs with very poor economy. 3. There is a lack of proper facility for inspection and repairs. 4. Provisions for reserve capacity are usually more expensive.

Plant capacity should be divided into 2 or 3 units properly proportioned for the load at various times of the day. In this way they can be operated most of the time with good individual machine load factors and consequently at much better economy. Such a layout will also afford an opportunity for proper inspection and repairs which will reduce the maintenance charges. The subject of reserve capacity should be carefully considered. In most cases it will not be found necessary to duplicate the plant in order to obtain the necessary reserve. With due regard for load conditions, overload capacities of machines and facilities for repairs, it will usually be found that from ⅓ to ½ of the plant capacity will constitute a conservative reserve allowance in prime movers. In the case of additions to existing plants the proposed units should be selected with the same care as would be used in the design of a new plant.

The character of the load will determine the type of the equipment to a certain extent. Some conditions require much closer speed regulation than others. In some cases the amount of exhaust steam required in the factory is in excess of the power plant consumption. It would be absurd in such a case to install an expensive unit which would operate at a high degree of economy.

In plants where power is transmitted electrically, the steam turbine has certain advantages such as good economy at varying loads and overloads, simplicity, close regulation, and small floor space. In many existing engine plants, in which extensions are contemplated, the exhaust turbine will prove to be an attractive proposition. In cases where it can be used to advantage, it will be found that the first cost of a given increase in capacity will be less than with the installation of a new high-pressure unit. In comparing such costs on a fair basis, it is necessary to include ground space, building, boilers, piping and auxiliaries. The exhaust turbine will show a better over-all plant economy in situations where its use is advisable.

No rule can be given for the fixing of the size or type of prime movers as it will depend entirely upon specific conditions. A careful study of such conditions will, however, in most cases, soon determine the proper solution.

SPACE AVAILABLE

FEW INSTALLATIONS of power equipment are made under ideal conditions. In much of the new work and nearly all of the additions or changes to present plants, the factor of available space has a decided bearing on the arrangement of the machinery and in some cases on the type and size of the units.

A compact arrangement of the apparatus in power plants is always desirable. In situations where the available space is limited, the most careful thought should be given to the arrangement of the equipment and several different layouts should be made. The operating characteristics of the machines should always be borne in mind and provision made for inspection and repairs. The more accessible apparatus is made, the more likely it is to receive proper care from the operating force. The designer should turn all his energies to the task of utilizing all the available room to the best advantage.

FUTURE EXTENSIONS, TRANSPORTATION AND FUEL

POSSIBILITY OF future extensions should always be considered and proper provision made in the layout of equipment and buildings. Such extensions can then be added with a minimum of expense and interference with operation and the plant arrangement can be followed out consistently.

When several different sites are under consideration for a plant, the railroad or waterway advantages are often the deciding feature. Handling of the equipment

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and materials during construction, and of coal, ashes and supplies in the operation, must be provided for. A proper use of such facilities during construction will also result in a saving of installation costs and time.

Thorough survey of the available sources of fuel should be made before the type of furnace is decided upon. In some cases oil, natural gas, wood, etc., may be used, but in the majority of plants the fuel used will be coal.

Different kinds of coal available in any locality should be studied with reference to cost at mines, freight rates, uniformity of product, probable increase in cost or freight rate, heating value, ash and nature of fuel as regards unloading and handling.

The disposal of ashes is a subject of considerable moment to plant operators. Ashes from some coals are in considerable demand by building contractors for use in filling, concrete, etc., and are readily sold. Other kinds of ashes have to be disposed of by the operator, often at considerable expense.

Unloading and handling of the coal should not be neglected. Some coals require crushing before they can be used. The finer grades of anthracite coal are "washed" to remove dust and impurities. This coal will freeze in the cars in cold weather and the unloading is a serious problem.

From the few points mentioned above it will be seen that the choice of the proper coal for a plant is a matter of considerable importance.

Water Supply

Water supply for boiler feed and condensing purposes should be fully investigated. An analysis of the boiler feed water by a competent chemist will always be a good investment. The writer knows of several instances where a failure to investigate the water supply properly, cost considerable money before the trouble was discovered and corrected.

Location

Location of the plant will affect some of the details. The discharge of steam traps and open exhaust pipes is objectionable in some places. Noise of operation and smoke from stacks will cause complaint. An excessive amount of dust and dirt may be present or heat and fumes from industrial operations. All such matters should be considered and proper care exercised in regard to them.

We will assume that the type, number and size of prime movers, the kind of fuel and the available water supply have been determined by a proper consideration of the principles pointed out above. The type and size of the other equipment can be readily fixed, when these 3 essentials have been decided.

Coal and Ash Handling

In large power plants extensive and elaborate systems are often installed, for the handling and storage of coal and the removal of ashes. In some cases they are necessary, but in other plants it is a question whether the expenditure of so much money is a wise investment. The competent engineer is the one who can produce results with the least expenditure. This should be particularly borne in mind when purchasing a coal-handling system. Complication not only means high first cost, but often excessive maintenance charges.

One of the simplest and best systems is an elevated trestle, parallel to the boiler fronts, upon which hopper-bottom coal cars are run and dumped. It is located near enough to the boilers so that the firemen can shovel direct to the fires. The advantages are low first cost, small maintenace charges, simplicity, no power required and cost of unloading coal, slight. The disadvantages are limited storage and lack of proper means of weighing.

Another plan is to install a suitable coal bunker over the boilers. This should be made no larger than is necessary for reasonable storage, in order to keep down the cost and minimize fire risk. The bunker should have valves in the bottom at suitable points, discharging into a traveling automatic coal scale, which weighs and records the coal used. This is not a refinement, as an accurate and efficient method of weighing and recording the coal delivered to the boiler room is essential, and of great assistance to the operator. It should be kept in good repair and frequently checked. In some cases a scheme of interlocking the scale with the coal valves might be of interest.

Coal may be delivered to the bunker in a variety of ways. When received by boat, a hoist and bucket, combined with a conveyor or a railway, either hand or automatic, may be used. When received by rail, a hopper underneath the track is necessary, usually built of concrete. Crushers, where used, may be placed in this hopper.

It may be elevated from the hopper by a bucket conveyor and distributed to the bunker by means of a bucket, screw or belt conveyor. In some cases, a good arrangement consists of elevating the coal by means of a skip bucket hoist and distributing with a belt conveyor. When a bucket conveyor is selected, it may be made continuous and used to handle both coal and ashes.

The drive on bucket conveyors should be located so as to pull the loaded parts of the conveyor and not push them. This should be apparent, but the writer calls to mind 2 instances where a neglect of this fact led to considerable trouble and finally to a change in location of the drive at large expense.

Where space is available for the approach, a scraper conveyor is well worth considering. It is low in first cost and has a large capacity, but the maintenance is high and it requires more power than some of the other types.

When coal crushers are required they should be of heavy construction and provided with ample driving power. Many of the standard crushers furnished by the manufacturers are entirely too light in construction and are subject to continual breakage and repair when in service. Unless the storage available is large it is well to provide 2 crushers.

Coal storage has not been considered for the reason that the expense is seldom justified in plants of the size and character treated in this article. Sufficient storage is usually found in the bunker and cars for ordinary conditions.

Ashes may be handled in several ways. For small plants a wheelbarrow is probably as good as any. Means should be installed for wetting the ashes in order to keep down the dust, which is hard on pumps, blowers, and other machinery.

Screw, bucket and scraper conveyors may be used, but they are subject to considerable wear and tear from

the dust, grit and heat, which will cause excessive expense in repairs and renewals.

Probably the best method for plants of the size under consideration is an industrial railway with some form of dumping steel car. This may probably be run under the boilers and combined with ash hoppers beneath the grates. The system is low in first cost, simple and subject to few repairs.

Suction ash systems for small plants are expensive and require a large amount of power to operate.

Lubrication

In turbine plants, lubrication is a simple matter. The horizontal units are provided with self-contained systems and the necessary apparatus for the vertical machines is furnished by the manufacturers. On vertical machines step bearing pumps should always be installed in duplicate and provided with pump governors. Where the plant contains several machines, an accumulator should be used. The turbine auxiliaries, such as dry vacuum pumps, should be provided with grease caps wherever possible. Oil filters should be installed in such a way that they are accessible for cleaning.

In engine-driven plants, each unit may be provided with its own system or a general system for the entire plant may be installed. In the latter method the oil when received is emptied from the barrel into a filter and settling tank. From this it is pumped to an overhead tank, which supplies the machinery by gravity through a proper piping system. The return from the various units is led to the filter. A gage glass should be placed on the overhead tank in such position as to be plainly visible to the operating engineer, so that the amount of oil in this tank may be readily observed. A bypass should be placed in the piping, so that in case of trouble with the overhead tank, oil may be pumped direct to the engines. Upon beginning operation, the amount of oil contained in the system should be determined, and all tanks and filters graduated on their gage glasses. It will then be a simple matter to check the quantity of oil on hand at any time.

In case each engine is provided with individual oil cups, the plant should be provided with a filter, so that all oil used may be properly purified.

There are many good devices on the market for feeding cylinder oil and the main point to bear in mind is to specify them large enough, so that they will not require too frequent filling.

On slow-moving machines and auxiliaries, grease cups can often be used to advantage.

Boilers

Individual boiler units should be chosen as large as is consistent with plant load factor and reserve capacity, but it should be possible to take a boiler out of service for cleaning without crippling the plant. All boilers should be the same size and of the same type, to facilitate repairs and allow the carrying of a smaller number of spare parts. There is practically no difference in the efficiency of the different types of boilers if they are properly installed and operated. Water-tube boilers are better adapted to high pressures and overloads and to conditions requiring quick steaming. The term boiler horsepower means little in power plant design. The steam requirements of the plant, in pounds per hour, can be determined from the characteristics of the prime movers and auxiliaries, with a proper allowance for losses. Right here it is pertinent to caution against too small an allowance for steam used by auxiliaries and plant losses, as these items are usually underestimated.

When the amount of steam required has been determined, the boilers may be proportioned with a sufficient amount of heating surface to supply it. The conservative figure has always been to assume an evaporation of 3 lb. of water per square foot of heating surface per hour. This can be forced to 4 lb. in most boilers and to 5 lb. in water-tube boilers, without seriously impairing the efficiency. Modern tendencies are toward much harder forcing of boilers than was considered advisable a few years ago. It is more a question of how much coal can be efficiently burned in the furnace than anything else.

Of the many different types of boiler furnaces and stokers, the efficiency is about the same when properly handled, and the decision in favor of a certain type will be based upon other considerations. Some stokers can be forced to high overload capacities. The great advantage of the mechanical stoker, in the opinion of the writer, is the fact that it requires fewer men, of less skill, to operate a boiler room. The subject of boiler-room labor is often a thorn in the side of the operating engineer and the stoker tends to decrease this trouble materially.

When the kind of coal has been fixed upon, careful thought should be given to such items as grate surface, type of grate or stoker, distance of furnace arches above the fire and their width, draft, and ashpit design. In many cases the boiler is placed too close to the grate even by the advice of the boiler manufacturers.

Where floor space is limited, a study should be made of the various sizes, types and makes of boilers, as a considerable variation in this direction will be found for a given total of boiler capacity.

Stacks are usually made large enough, but often the flues and breechings are not properly designed and cut down the draft materially. The breechings and flue should be amply large, air-tight, have no sharp turns, be properly supported and provided with necessary cleaning doors.

Heaters

In most plants it will be found that a feed-water heater of some kind is required for maximum economy of operation. It may be either an open or closed heater or an economizer. The open heater may be combined with a purifier, or a feed-water measuring device, or both. The open heater can be used in the majority of plants and is preferable in such cases. Sometimes it may be profitable to install an economizer to heat the feed-water further after it leaves the heater. When open heaters are used, they must be placed above the pumps, in order to insure proper operation of the latter on hot water.

Heaters should always be placed in an accessible location, so that they may be easily and properly cleaned. In comparing various heaters, before purchasing, one point to be considered is the velocity of the water passing through. This should be low enough to allow of efficient operation.

Measuring and Pumping Water

The designer should provide for accurately measuring and recording the boiler feed-water. The importance of weighing the coal has been previously mentioned. A proper record of both coal and water is essential to plant economy and nothing can be definitely determined in this direction without such records. It is the duty of the designer to provide the means of obtaining this data and money spent on such apparatus will prove a wise investment.

The most important pumps in the plant are those for boiler feed. They should be chosen with an ample margin, both for capacity and pressure. Such pumps should always be installed in duplicate and proportioned to run at a slow speed, which will tend to decrease the strain on pumps and piping, and ensure long life and reliability. Outside packed pumps are preferable for this work and for high pressures the pot-valve type is superior. They should be provided with pressure regulating valves between the pump steam chest and the throttle valve. In many localities it will be necessary to have the pumps fully bronze fitted on account of impurities in the boiler feed-water.

When a general service or other pump is necessary in the plant, it is a good plan to provide a pump that will, for limited periods, be able to work on boiler feed and cross connect the piping, so that it may be used as such in an emergency.

Where centrifugal pumps are used for any purpose, particular attention should be given to the method used in different designs for packing the shaft against air leakage. This is a fruitful source of trouble and profanity for the operating man and the detail should be simple and readily accessible for inspection and repair.

Piping

Piping of the various machines is important. Buy the best material and have it installed by a competent steam fitter. See that it is properly supported and that provision is made for expansion and anchoring. Simplicity of arrangement is of prime importance, both on the score of first cost and ease of operation. The fewer valves a man has in front of him when trouble occurs, the more likely he will be to open or close the right one. In many systems of piping which have come to the notice of the writer, the complication was nothing short of criminal. Keep the piping out in the open as far as possible, to facilitate inspection and repairs. Use long bends at turns and avoid pockets and dead ends. Do not use screwed pipe except in the smallest sizes. Use valves which can be packed under pressure and in the larger sizes use outside screw valves with rising stem; a glance will tell whether they are open or shut. A plain, single-line, schematic diagram of the power plant piping should be drawn up, framed and hung in the power station for the information of the operators.

The main steam piping of the plant should be as direct as possible from the boilers to the prime movers, using few pieces of pipe in order to reduce the number of joints. All bends should be long radius and can in many cases be combined with a straight run to simplify the system. Pay careful attention to the drip system and provide for expansion. Each boiler should be provided with a nonreturn valve. Gate valves are preferable in main piping. Except for low pressures, some type of flange similar to the Van Stone should be used. The Holly system is effective for high-pressure drips. If traps are used they should be chosen of ample size and with liberal valve opening; it is a common error to choose a trap which is too small. The frequent discharge cuts the valves and seats of the trap and soon causes it to leak and require repairs.

Piping should be proportioned for a steam velocity of 5000 ft. a minute in steam engine work and from 8000 to 10,000 ft. a minute in turbine work. Separators are necessary for engines and advisable in many cases on turbines. Pipe covering of the best quality and of suitable thickness should be provided.

Full weight pipe is ample for any pressure up to 200 lb. with extra heavy flanges, valves and fittings for pressures over 125 lb.

Boiler feed piping should be extra heavy real wrought iron, with extra heavy flanges, valves and fittings. A water relief valve should be provided at the pump in order to prevent building up excessive pressures on pump and piping. Use gate valves and long radius bends on long-turn elbows. Piping should be braced and anchored to eliminate vibration and hammering as far as possible. Boiler feed regulators may be used to advantage and piping carrying hot water should be covered. Piping should be proportioned for a velocity of about 200 ft. a minute on the suction end and 400 ft. a minute on the discharge end.

Ordinary standard weight pipe may be used in the exhaust with low-pressure valves and fittings. The system should be properly provided with drips and suitable covering installed. In cases where an open heater is used an oil separator or eliminator on the exhaust line is essential to keep the oil from being carried over into the boilers. This apparatus is often built into the heater itself; but when a separate one is purchased, care should be taken to see that it is large enough.

Piping and fittings for the oiling system should be of brass or galvanized iron to eliminate dirt and scale. Tees with plugs, should replace elbows at proper locations to allow of thoroughly cleaning the system. The oil return piping to the filter should be pitched sufficiently to ensure a free flow of oil.

When condensers are used, the water supply and discharge piping should be flanged cast-iron and the suction pipe must be provided with a strainer, preferably of a type which will allow cleaning while in operation.

Drawings should be made of all the smaller miscellaneous and auxiliary piping, to ensure proper layout. This piping is too often neglected and left to the rule-of-thumb methods of the ordinary steamfitter. The drawings do not need to be elaborate, but may be single line sketches to scale. Necessary pipe covering should be provided and the piping well supported and anchored.

Drips

This important feature of plant piping should receive the best attention, from the standpoint of safety and economy. A comprehensive drip system should be installed in every plant to return all hot water to the heaters or boilers. It may usually be divided into 2 parts, viz: high-pressure drips and low-pressure drips. The 2 systems should be laid out so as to require the minimum number of steam traps.

Many small steam traps located in obscure corners are the bane of the operating force. The writer once made some changes in a plant and redesigned the drip system. Six high-pressure and 8 low-pressure steam traps, were replaced by 1 high-pressure and 2 low-pressure. This is, of course, an extreme case but illustrates the tendency in some plants. The high-pressure traps or Holly system return the water direct to the boilers. The low-pressure drips ordinarily contain considerable oil and should be emptied into a skimming tank and sent through an oil filter, before being returned to the heater or boiler feed pump suction.

Drip piping should be covered and the runs made as short and direct as possible. Traps should be chosen of ample size, placed in accessible locations and properly bypassed, so that they may be quickly inspected and repaired.

Instruments

Records and comparisons are necessary for sustaining and improving plant economy. Instruments for these should be provided and they should be considered as much a part of the original plant equipment as the engines and boilers. In the boiler room a CO_2 recorder and a recording boiler pressure gage should be installed. Recording instruments can be placed to advantage on the temperature of the boiler feed-water, the condenser circulating intake and discharge, and the hotwell. Draft gage and barometer should be supplied and when the plant is run condensing, a mercury column should be used to indicate vacuum. A simple fuel calorimeter—such as the Parr—a reliable gage testing set, an indicator for steam engine work and a good tachometer are real necessities in a modern plant.

There is entirely too much of a tendency to regard such items as a refinement or to assume that they should be furnished by the plant operators. Their cost is a small item when compared to the total cost of the plant and their use is essential to intelligent and economical operation. The plant should be turned over to the operators complete in every detail, giving them full responsibility for efficiency and economy. If the equipment has been properly executed, the result will be an incentive to the efficient operator and will not serve as an excuse for the inefficient.

Pressure and Vacuum Gages

Pressure and Vacuum Indicated by Various Types of Gages

PRESSURES of steam, water, air, and gas, are of prime importance in power plant operation, and, accordingly, should be determined by some accurate and reliable means. For the purpose of indicating pressure and vacuum, 3 general types of gages are employed, the Bourdon type, the diaphragm type, and the manometer, or U-tube. Gages of the Bourdon and diaphragm types consist of 2 essential parts, the pressure element and the movement.

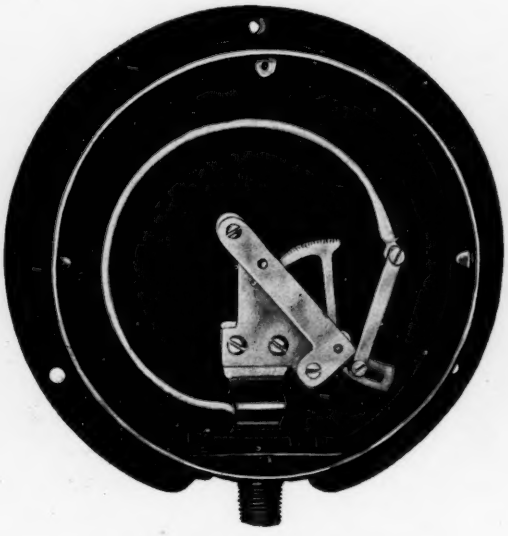


FIG. 1. BOURDON GAGE WITH MOVEMENT MOUNTED ON TUBE SOCKET

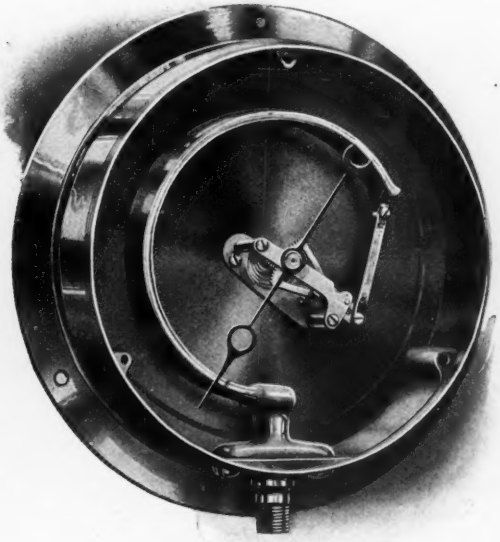


FIG. 2. BOURDON GAGE SHOWING MOVEMENT MOUNTED ON BACK OF CASE

In gages of the Bourdon type, Figs. 1 to 6 inclusive, pressure is applied internally to an elastic hollow brass or steel tube of oval section, bent into the shape of a circular arc and closed at one end. Since the closed end of the tube is free to move, while the other end is fixed, fluid pressure on the inside tends to increase the short diameter of the section, causing the radius of curvature of the whole tube to become larger, thus mov-

ing the free end a distance proportional to the pressure applied. By connecting a suitable multiplying mechanism to the end of the tube, a needle or pointer may be moved so as to indicate on a graduated dial the pressure in the units desired.

Generally, the multiplying mechanism, which is illustrated by Fig. 7, is made up of one or more levers, a toothed segment or sector, a pinion, and a hair spring.

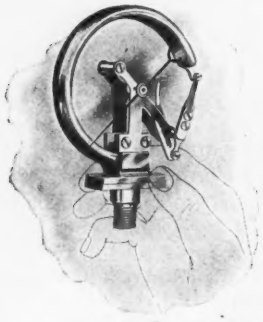


FIG. 3. BOURDON TUBE AND MOVEMENT INDEPENDENT OF CASE
FIG. 4. BOURDON GAGE WITH MOVEMENT ATTACHED TO BACK OF CASE

Adjustment of the ratio of movement between the pointer and the end of tube is made by either a slotted sector arm or connecting link, whose length may be readily changed to suit conditions. Lost motion of the parts is taken up by the hair spring, which is attached to the spindle carrying the pointer.

Owing to the vibration of the pointer due to the jarring which occurs in certain classes of service, also the rapid fluctuation in pressures sometimes encountered, double spring gages, Fig. 5, are sometimes used. The pressure tube in such a gage may consist of 2 separate branches or may be continuous, but in either case there are 2 free ends, which when properly connected by a lever mechanism, give a greater movement of the pointer than is obtained with a single spring.

In Fig. 6 is shown an auxiliary spring gage, the functions of this auxiliary coil spring being to return the free end of the tube to its original position when the pressure is removed, thus offsetting any tendency toward a permanent set, and to minimize the whipping of the free end of gage tube under excessive vibration.

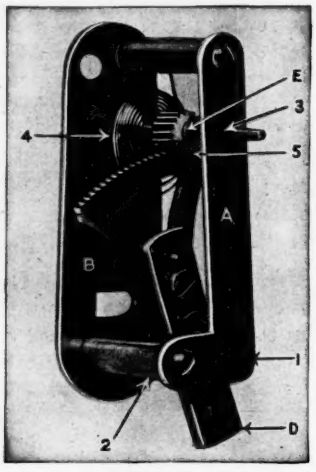


FIG. 7. MULTIPLYING MECHANISM

In order to permit the use of thin metal in its construction, thereby increasing its elasticity and resiliency, and at the same time maintain its strength, the Bourdon tube is sometimes made with one or more corrugations, on its long or flat side, as shown by Fig. 5.

In the diaphragm gage, Fig. 8, the indicating device is actuated by a corrugated metal disk or diaphragm, which is clamped around its edge by the flanges of an encircling chamber. The deflection of the diaphragm is proportional to the pressure applied to its lower side, and its movement is communicated to the pointer by a mechanism similar to that employed in the Bourdon type.

FIG. 5. DOUBLE SPRING BOURDON GAGE WITH CORRUGATED PRESSURE TUBE

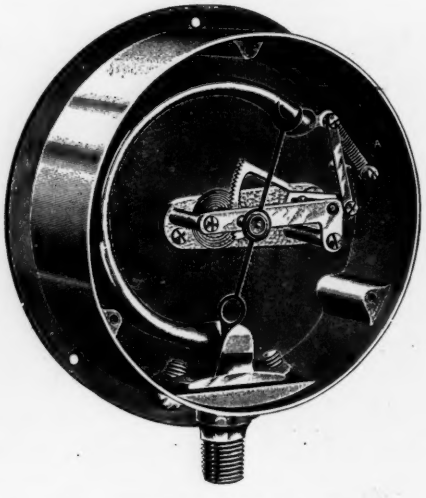


FIG. 6. BOURDON GAGE OF AUXILIARY SPRING TYPE

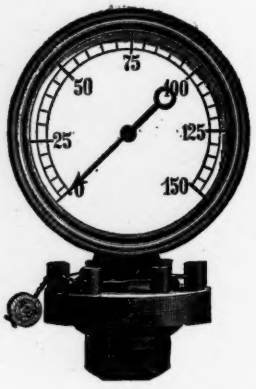


FIG. 8. DIAPHRAGM GAGE

Manometers, or U-tubes, which consist merely of a glass tube bent into a U-shape, and partly filled with a liquid such as mercury or water, are simple and sensitive instruments for measuring pressure or vacuum, as they have no working parts to become deranged. If one branch of the tube is connected to the source of pressure and the other end left open to the atmosphere, the difference in level of the liquid in the 2 branches of the tube will indicate, on a properly graduated scale, the pressure or vacuum in inches of mercury, water, or whatever unit may be desired. The U-tube is suitable, even when filled with mercury, only for comparatively low pressures, being limited by the inconvenience due to its length or height.

For the measurement of vacuum, which is the difference between absolute and atmospheric or barometric pressures, both the Bourdon and diaphragm types are commonly used, the design of the gage being altered only in the arrangement of the levers to accommodate the reversed movement of the tube or diaphragm.

Bourdon gages can be used for indicating pressures of liquids, steam, or gases, where the tube does not reach a temperature much in excess of 150 deg. F., as above this limit the temper of the tube is likely to be affected. When used for steam pressures, therefore, a siphon must always be used to prevent steam coming into contact with the tube, and should be of sufficient capacity to fill the gage tube with water.

Various gages of the Bourdon type are manufactured, the chief differences being in the details of construction. The distinctive features are the material and mounting of the tubes and movement, and the smooth action of the gearing. The movement may be mounted on the back of the gage, or on the gage socket, the claim for the latter construction being that it removes liability of the movement being thrown out of adjustment while the gage is being screwed into position, and of overheating of the tube on account of the air space surrounding it. To secure and maintain the greatest possible accuracy, the tubing should be properly selected and seasoned to remove all natural set, and the gearing should be cut with precision. Also the moving parts should be free, so far as possible, from wear and friction, noncorrodible material being generally used.

Flow Meters

MEASUREMENTS OF STEAM AND WATER BY METERS AN AID TO ECONOMY

IN operating a plant at its highest efficiency, an accurate knowledge of the quantity of water and steam is essential. These may be conveniently measured by one of the various forms of flow meters, common among which are the Pitot tube, the Venturi meter, and the valve automatically lifted from its seat, rising or falling as the quantity increases or decreases, the position of the valve indicating the rate of flow.

Pitot tubes consist of 2 small tubes, one of which is usually placed within the other and arranged so that when inserted in the pipe, or main, the opening in one tube faces against the direction of flow, while in the other the opening faces in the direction of flow. By connecting the other ends of the tubes to the legs of a U tube, or to some measuring device, the flow may be indicated on a properly graduated scale in the units desired. Similarly with a Venturi tube the difference of pressure, or velocity pressure, between the upstream side and throat of the tube is transmitted by 2 small pipes to a suitable metering device.

Water under pressure, such as boiler feed, is ordinarily measured by a meter placed on the discharge side of the pump, with provision for calibration without shutting off the feed supply to boilers. Among the types of water meters in use are the piston type, in which reciprocating pistons are displaced by a definite volume of water, and the rotary type, which depends upon the moving of rotating impellers. In still another type the water flow is determined by a weir. Pitot tubes and Venturi meters are also adapted for measuring water.

Venturi Meters

BUILDERS IRON FOUNDRY, PROVIDENCE, R. I.

FOR the continuous measurement of the flow of water and steam through pipes, the Venturi meter has met with great success. Primarily, this may be said to be due to the fact that a high differential pressure is obtained with practically no final loss of pressure. The principles embodied are as follows:

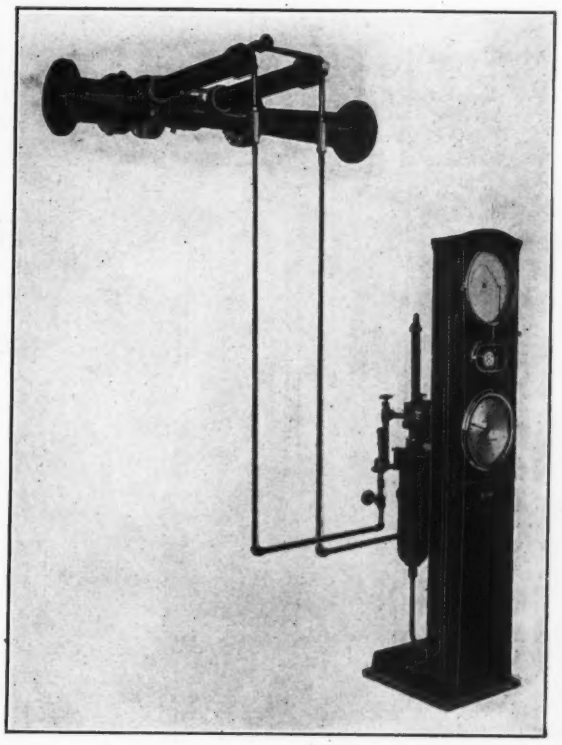


FIG. 3. REGISTER INDICATOR-RECORDER AND CONNECTIONS TO VENTURI TUBE

When water flows through a pipe containing a contraction, or throat, like that in Fig. 1, the pressure at B will be less than at A, due to the increased velocity at B. In a properly designed pipe, however, this drop of

pressure will be almost entirely regained at the outlet C, this, in turn, being due to the decrease of velocity after the water passes the throat B. These facts may be verified by inserting pressure gages at A, B and C. By means of a U-tube containing mercury, the drop of pressure between A and B may be accurately measured, and always bears a definite relation to the rate of flow or velocity at B. Two small pipes, connected to the inlet and throat of the tube, transmit the difference of pressure at these points to the meter or registering device. At the back of the register these pipes enter 2 large vertical wells, connected at the bottom by a small pipe, one well being subjected to the inlet and the other to the throat pressure of the tube. In each well is a heavy metal float resting upon mercury, which flows from one well to the other in direct proportion to the difference of the 2 pressures, causing one float to rise as the other descends, the movement being transferred through rack and spur gearing to the indicator dial hand shaft. A cam, Fig. 2, on this shaft controls the position of the pen on the chart and also the amount of movement of the counter-dial figures.

FIG. 1. DIAGRAM OF VENTURI TUBE

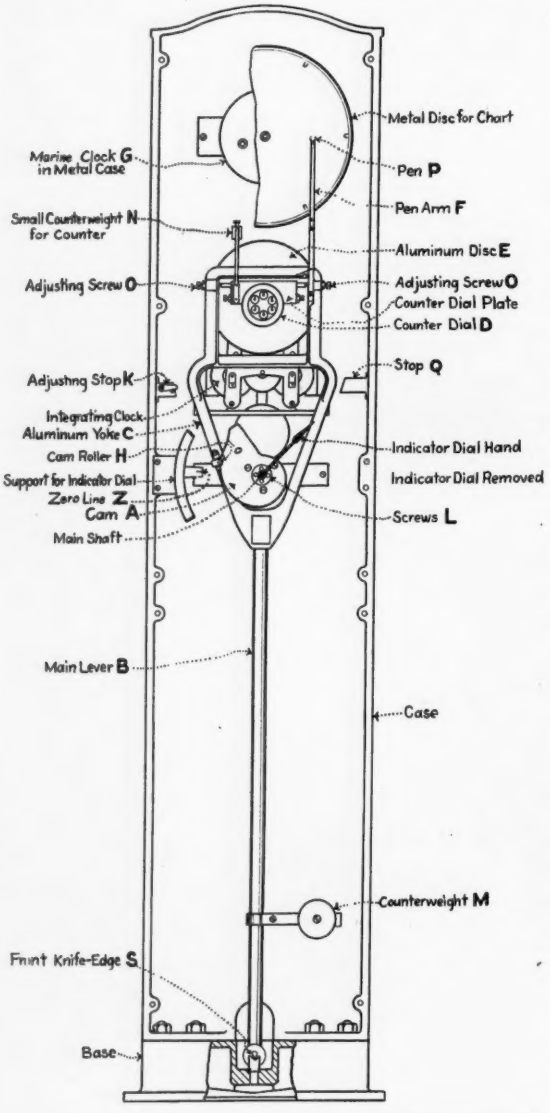


FIG. 2. INTERIOR VIEW OF REGISTER MECHANISM

This register is simple in construction and positive in action, responding to minute variations in the rate of flow. Bronze, aluminum and other noncorrodible metals enter largely into the construction of the interior parts. The main case is of cast iron, painted black on the exterior. The dial rims are nickeled, and the indicator dial machine-engraved and silver plated, making this type of register indicator-recorder entirely appropriate for the most up-to-date engine room or superintendent's office. The indicator dial is 30 in. in circumference and consequently can easily be read to within ½ of 1 per cent, showing the exact rate of flow in pounds per hour. For this reason it is of great value in making short tests, during which frequent readings may be taken, averaged and multiplied by the elapsed time to obtain the total flow during the test. The counter dial registers the total pounds of water which have passed through the meter tube and is similar to the dial of an ordinary water meter. The recorder dial carries a circular chart 12 in. in diameter and furnishes a continuous record of the rate of flow. The chart makes one complete revolution in 24 hr., unless desired otherwise. By means of the chart record, a great increase in economy often may be introduced by checking waste and improving efficiency in manufacturing operations.

For the measurement of steam the same principles are employed as for the measurement of water. The meter tubes and the various types of indicating, recording and registering instruments are similar for both kinds of service. Each meter is graduated for the steam pressure under which it is to operate and, if this pressure varies materially, the observed readings may be multiplied by a factor, depending upon the average pressure obtained during the working period. When steam is measured, a horizontal condensing chamber, Fig. 3, of simple construction, is placed in each of the small-pressure pipes close to the meter tubes, the purpose being to keep an equal head of water in both pressure pipes when variations in flow occur. The 2 pressure pipes may be as long as desired, allowing the registering instrument to be conveniently located.

G-E Flow Meters

GENERAL ELECTRIC CO., SCHENECTADY, N. Y.

FOR various classes of service, the General Electric Co. has built several types of steam meters, among which are an indicating recording meter, a graphic recording meter, an indicating meter for permanent installation and a portable indicating test meter.

For measuring the velocity of steam in pipes larger than 2 in. in diameter, a nozzle plug, Fig. 1, is screwed into the pipe, while with pipes 2 in. or less in diameter,

an orifice tube, Fig. 2, is inserted as a portion of the pipe line. The nozzle plug, which is a modification of the Pitot tube, is composed of a double-conduit tube extending across the pipe diameter, each conduit having a separate set of openings. The orifice tube is similar in action to the Venturi meter.

In case the velocity is too low to be accurately measured, a pipe reducer is used. This consists of a metal funnel insertion between and held in place by 2 flanges

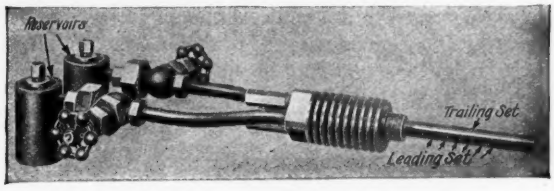


FIG. 1. NOZZLE PLUG AND CONNECTIONS FOR OBTAINING VELOCITY OF FLOW IN PIPES LARGER THAN 2 IN. IN DIAMETER

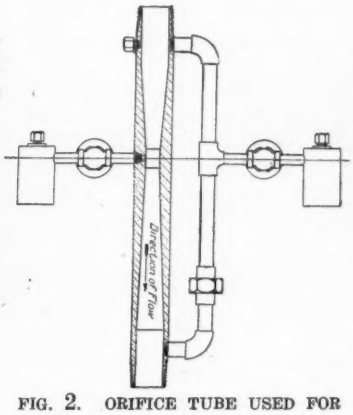


FIG. 2. ORIFICE TUBE USED FOR PIPES 2 IN. IN DIAMETER OR LESS

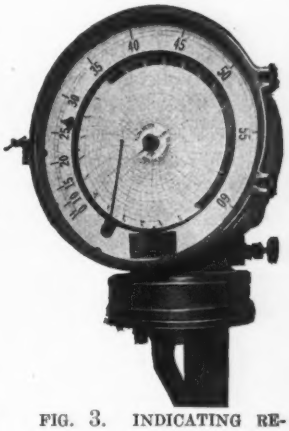


FIG. 3. INDICATING RECORDING FLOW METER

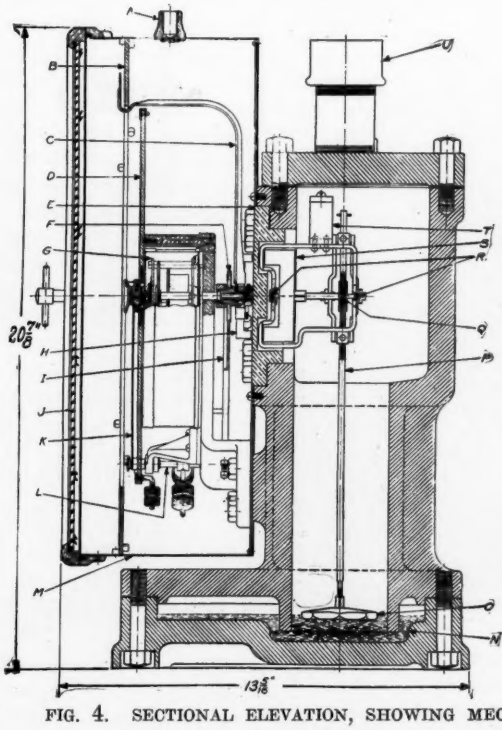


FIG. 4. SECTIONAL ELEVATION, SHOWING MECHANISM OF INDICATING, RECORDING FLOW METER

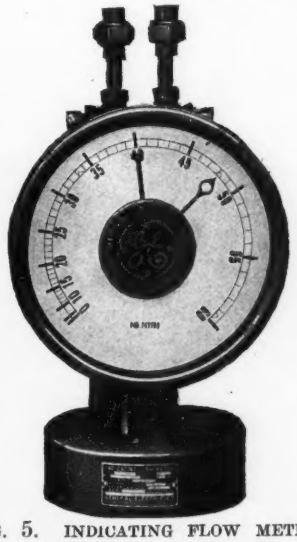


FIG. 5. INDICATING FLOW METER FOR PERMANENT INSTALLATION

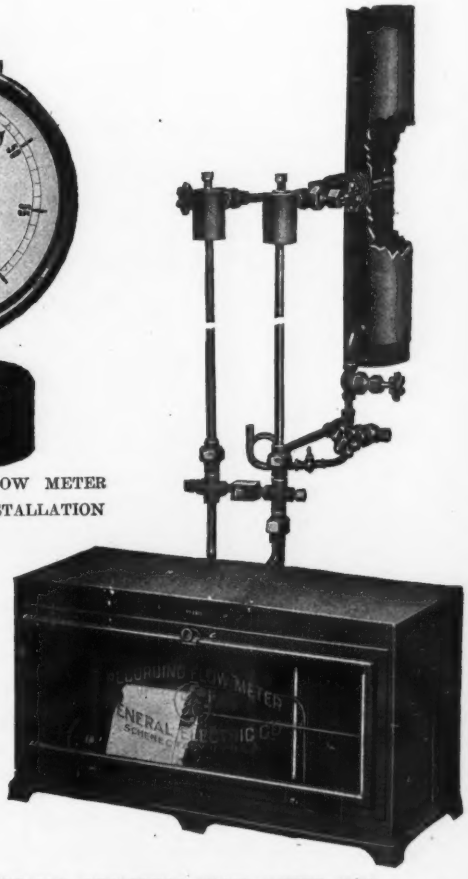


FIG. 6. PORTABLE RECORDING FLOW METER CONNECTED TO NOZZLE PLUG; METER ENCLOSED IN CASE

of a pipe. Where a pipe reducer is used, the nozzle plug is screwed into the pipe and projects through a hole in the reducer.

By means of ¼-in. piping, connections are made between the nozzle plug or orifice tube and the meter, which may be located in any desired place above or below the point where the flow is to be measured.

Figure 3 shows the indicating recording flow meter, which, as its name implies, both indicates and records the steam flow. The indicating scale is calibrated in pounds per hour or boiler horsepower, as preferred, for a given condition of pipe diameter, pressure and quality, and the meter cannot be used under conditions other than those for which it is calibrated. The chart is graduated in arbitrary units from 0 to 10 and a multiplying constant is used to reduce chart readings to values representing the flow in pounds per hour or boiler horsepower.

Similar to the indicating recording type of meter is one with the indicating scale plate and indicating needle omitted, making it possible to use a somewhat smaller case.

Either the indicating-recording or recording meter may be equipped with an integrating attachment which automatically adds up the values of flow plotted on the circular chart.

Figure 4 shows a sectional view of the indicating recording meter. The body of the meter consists of an iron casting, so designed as to form one leg and mercury well of a U-tube system. The other leg is formed by the pipe going into the mercury well. An iron float, O, attached to a circular rack, P, rests on the surface of the mercury in the large leg of the U-tube. The rack engages a pinion, Q, on a shaft carrying a large horseshoe magnet, S, which has its pole faces near the copper plug, E, bolted on the body of the casting. Outside the U-tube is another horseshoe magnet, H, mounted with its pole faces near the copper plug, and with its axis of rotation in alinement with the shaft carrying the magnet inside the meter. The indicating needle, C, is attached directly to the outside magnet, H, and a pinion, F, on the shaft of this magnet engages the sector, I, the shaft of which carries the recording pen. Any difference of pressure caused by the flow of steam, forces the mercury to rise in the leg containing the float. By means of the float and rack the pinion carrying the magnet is rotated and the motion of this magnet is, in turn, transmitted magnetically to the outside magnet carrying the pointer, causing the needle and pen to deflect in proportion to the change in level of the mercury.

Figure 5 shows a type which is designed to be installed permanently in a pipe. It will indicate the instantaneous rate of flow and is calibrated for a given pipe diameter, pressure and quality. The internal mechanism of this meter is much the same as the one previously described, except that, instead of the rack, the float has attached to it a silk cord, passing over a pulley, the cord being kept taut by a counterweight. A target, which is easily set from the outside, is provided for designating a certain flow on the scale.

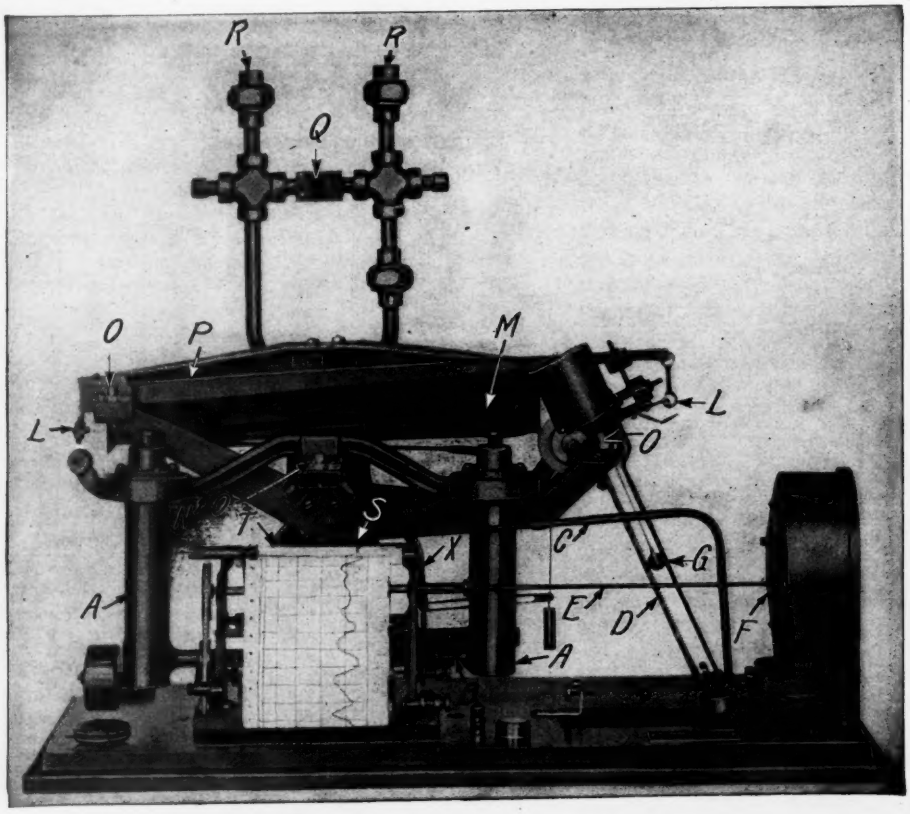


FIG. 7. MECHANISM OF RECORDING FLOW METER WITH AUTOMATIC PRESSURE COMPENSATING DEVICE

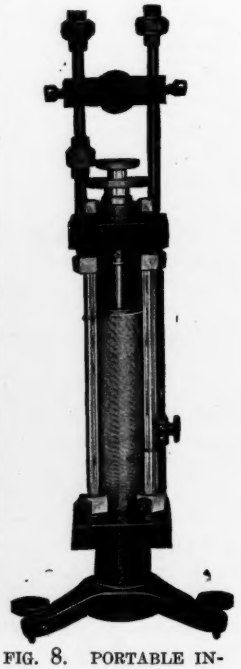


FIG. 8. PORTABLE INDICATING FLOW METER

Figure 6 is suited for general use where a light, portable recording meter is preferred. It can be adjusted for any condition of pipe diameter, pressure or quality within a certain range. Since it is equipped with a record roll, instead of a circular chart, it is found useful for testing where the flow varies rapidly in amount, necessitating a fast paper feed. This meter can be furnished with a pressure compensating device which automatically corrects for variation in static pressure.

The mechanism of this type meter is seen in Fig. 7. The 2 branches of the nozzle plug, or orifice tube, are connected by flexible tubing, M, to the tops of the hollow cups, A, which are about half filled with mercury and are joined by a connecting tube at the bottom. A

curved arm, N, extends across the top of the cups and carries at its center the knife edge, O, upon which the cup system is free to swing through its slight working movement. A difference of pressure, due to the flow of steam, forces mercury to rise in the left-hand cup, causing that side of the cup system to move downward slightly until balanced by the moment of the counterweight on the right-hand side. The motion of the cup system is transmitted at the left to a multiplying beam P, which, in turn, is connected at the right to a bell-crank lever that acts as a counterbalance arm. The pen arm C is pivotally connected to the lower end of the counterbalance arm at the point of maximum movement of the system. Thus, the motion of the cup system, multiplied by the levers, actuates the pen, S, which moves in proportion to the mercury displaced.

Cochrane Feed-Water Meter

HARRISON SAFETY BOILER WORKS, PHILADELPHIA, PA.

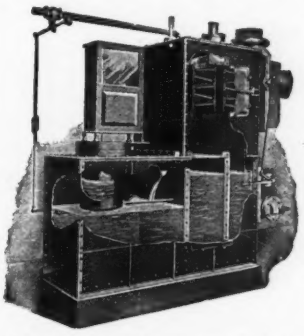
BY the use of the open weir, many of the difficulties encountered in the measurement of flow of hot water are overcome. In plants where open feed-water heaters are used, the feed-water must be measurd at some point between the heating trays and the boiler—that is, after the water has been completely assembled, including the steam condensed in heating the water. Since a still water chamber or suitable approach channel is required for the proper operation of the weir, the settling chamber of the open feed-water heater is utilized as the still water chamber for the weir, and a float in the discharge chamber of the heater controls the cold-water inlet valve, admitting water to the heater.

By thus enclosing the weir within the heater, water at any temperature, as 212 deg. F. or higher where back pressure is carried, can be measured without loss of heat or water through the escape of vapor. With this arrangement, space, valves, piping, etc., are economized and pulsations, caused by the action of the pump, are absorbed, owing to the storage capacity, which acts as a receiver, insuring legible records. Also impairment of the accuracy of the meter, due to the accumulation of scale or sludge, is easily prevented.

For very large flows, the most common type of weir is the rectangular or other form of notch bounded by more than 2 sides, but for accurate work in measuring relatively small flows, the triangular or V-notch type of weir has come into extensive use, because it is easily standardized and is sensitive and efficient at small flows.

In the figure the manner of applying the V-notch for the measurement of hot feed-water in the metering heater is shown. The heater, which is of cast-iron construction, containing 3 chambers—the heating chamber, the still-water chamber, or approach channel to the weir, and the outflow chamber, in which is located the float controlling the admission of water.

In connection with these metering heaters, a simple registering and recording mechanism is employed. Referring to the illustration, will be seen a large copper float located in a chamber connected through a throttle valve with the still water chamber, and enclosed within the heater construction, so that it is subjected to the vapor pressure existing therein. A brass rod, attached to the float rises vertically through a stuffing box in the roof of the cover of the meter chamber, from which it passes through a second vapor gland into the recorder casing, where it operates a spiral cam. The design of this cam is such that the pen actuated by it, travels equal



COCHRANE METERING HEATER, SHOWING APPLICATION OF V-NOTCH TO METERING HOT BOILER FEED-WATER

distances horizontally for equal increments in the rate of flow, tracing a record of the flow of water in pounds per hour. The chart upon which the record is made is wrapped around a drum, revolved once in 24 hr. by an 8-day clock.

"Sarco" Steam Meter

SARCO ENGINEERING CO., NEW YORK

ACTION of this meter is based upon the loss of pressure when steam flows from one vessel to another, this loss being proportional to the quantity of steam passing. In the application of this principle of the "Sarco" meter, a disk, Fig. 1, of 11/16-in. thickness, and such diameter that it is held in position by the bolts surrounding it, is placed between 2 flanges at a point in the pipe line, where it is desired to measure the weight of steam passing. The disk has a bore slightly smaller than that of the pipe, causing the steam to be throttled to the extent of a drop in pressure of about ¾ lb. per sq. in.

Difference in pressure on the 2 sides, which is the medium through which the flow of steam is determined, is conveyed to the instrument through copper pipes of ¼ in. or larger internal diameter, which connect with holes drilled in the disk, and communicate with the high and low-pressure sides. For vertical pipes the outlets of these connecting pipes are counter-sunk, Fig. 1, in such a way that no water can collect in the bore, which points upward, as this would cause an unequal head on the 2 sides of the meter.

By means of a 3-way cock, 7, Fig. 2, the high-pressure side of the throttle disk is connected to the pipe, 9, leading into a mercury reservoir, 10, which, in turn, connects to a hollow cone, 12, through a tube, 11.

Cone 12 is suspended by means of spring 26, and has a connection, 13, at its upper end, which gives access to the low-pressure side of the disk through a special port and the tube, 8. It will be seen that the higher pressure, acting through the water in the connecting tubes upon the mercury in 10, will tend to drive this out along tube 11, causing the cone, 12, to sink,

On the other hand, the low pressure from the other side of the disk will press on the surface of the mercury through 8 and 13, tending to force it back into 10. The difference between the 2 pressures will determine the position on the cone, 12, whose movements are recorded on a diagram, 17, by means of the pen gear, 16, operated through levers 14 and 15.

The chart, which is driven by clock work, is arranged for 24 hr. and is calibrated in pounds of steam per second. The chart and throttle disk to correspond are varied for each different size of pipe, and arranged so as to permit the maximum flow of steam likely at the point in question to fall within the range provided.

Where it is desired to have a record of the total flow of steam over a period, an integrator is fitted. This consists of a disk, 20, driven by a separate clock movement, and a friction gear, 18, suspended from the pen lever, 15, and moving up and down with it on the surface of the disk, 20. A friction wheel, 19, is driven by the disk, and, by means of a worm gear, causes the pointer, 22, to move around dial 21. The speed of the pointer will then depend upon the position of 19 with respect to the periphery of disk 20. The dials are calibrated in pounds of steam and are read once in 24 hr.

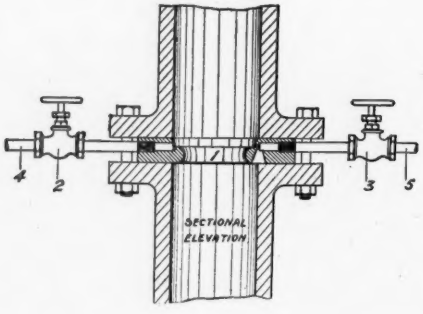


FIG. 1. THROTTLE DISK IN VERTICAL PIPE

Since accurate results can be obtained with the instrument only when the steam pressure is constant, automatic compensators are used where fluctuations exceeding 5 per cent have to be dealt with. These regulators consist of an oil chamber, 30, which communicates through small holes with a piston, 31, whose piston rod, 32, is held down by a strong spring, 33, connected to the segment lever, 34. The regulator is put under pressure through tube 28, connected at 27, and controlled by the valve, 29. When piston 31 is forced upward, the spring, 33, expands, and this causes lever 34 to swing downward, thus shifting the fulcrum of the pen lever and automatically correcting the chart and integrator readings.

In addition to the recording meter, a simple form of indicating instrument is made, constructed on the same principle as the recorder, but primarily intended for use as a load meter. The meter itself is a modified U-gage, filled with mercury, one side being connected to the high, and the other to the low-pressure side of the disk.

Sargent Steam Meter

SARGENT STEAM METER CO., CHICAGO

THIS meter depends for its operation upon the law that pressure times volume equals a constant. Roughly, the same quantity of steam under 50 lb. pressure will flow through a given opening as will flow through one of half its area at 100 lb. pressure.

Figure 1 shows the valve, valve stem and spring, the only moving parts in the meter. The Bourdon spring moves the indicating needle transversely, while the valve stem, which has a vertical movement with the valve, raises the needle vertically.

Figure 2 is a sectional elevation of the meter. Steam entering at the left passes up around the valve stem, and

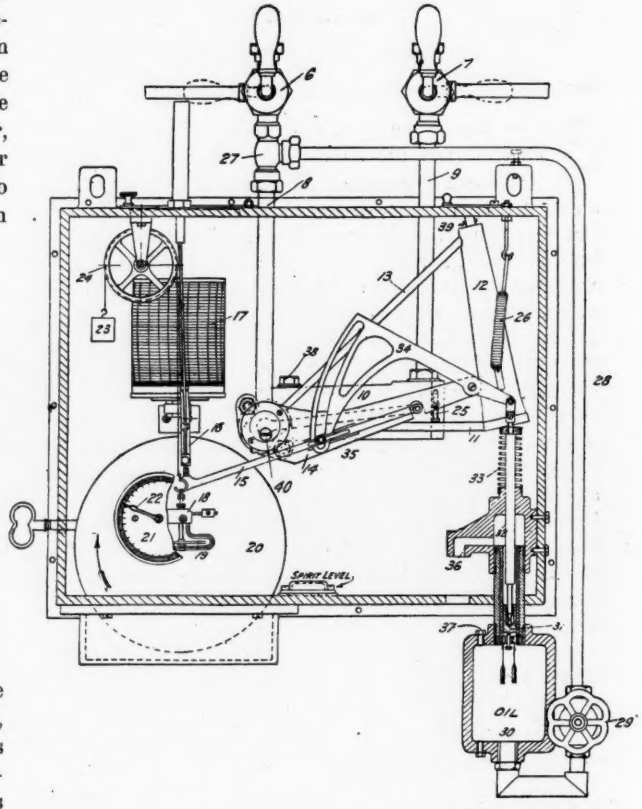


FIG. 2. SECTIONAL ELEVATION OF "SARCO" STEAM RECORDER WITH CHART DRUM, INTEGRATOR AND PRESSURE REGULATOR

as the pressure increases, flows through the opening, P, raising the valve, I, from its seat and permitting the steam to pass down between the inside and outside cones to the discharge at the right of meter, as shown by the arrows. The valve stem, K, is open to atmospheric pressure at its lower end, and as the area of the stem is about 2 per cent of that of the valve, there must be a difference of pressure between the inlet and outlet sides of the meter of 2 per cent in order to raise the valve and maintain it in equilibrium.

With a constant steam pressure and correct calibration, the quantity of steam flowing would be proportional

to the rise of the valve, but as the pressure varies the needle moves horizontally, so that any quantity of steam passing through will be indicated by the needle, regardless of pressure, provided that both are in the calibrated range.

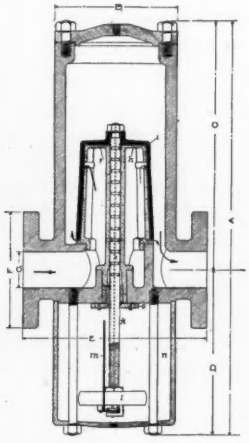


FIG. 1. VALVE AND SPRING WITH INDICATING NEEDLE ATTACHED

FIG. 2. SECTIONAL VIEW OF METER

Each meter is calibrated separately by weighing the condensation, and the curves on the dial are made from the results thus obtained. The meters are tested with commercially dry steam and indicate the steam flow in pounds per hour or boiler horsepower, as desired, 30 lb. per hour being taken as one boiler horsepower.

Simplex Water Meter

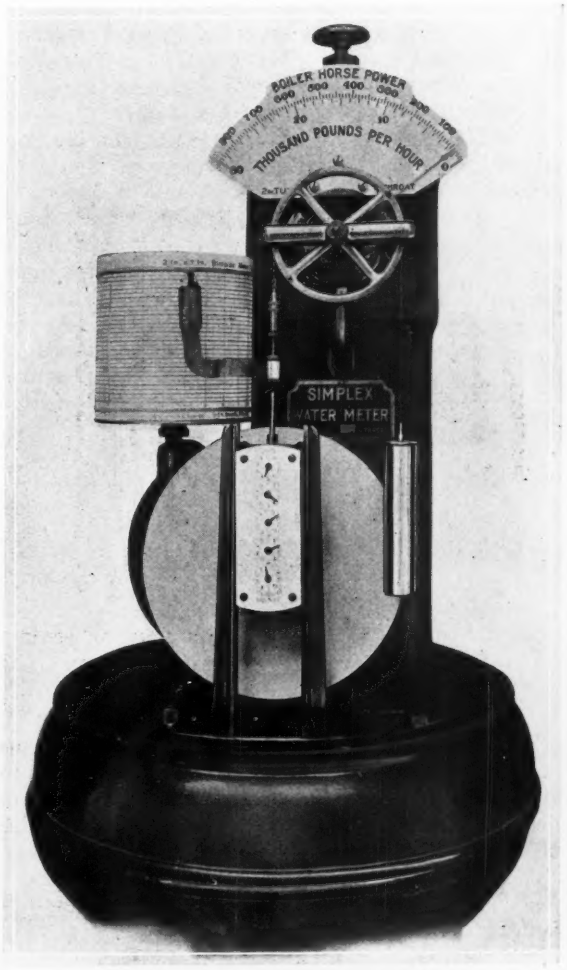
SIMPLEX VALVE AND METER CO., PHILADELPHIA, PA.

THIS instrument is used in connection with Venturi and Pitot tubes, having suitable pipe connections therewith to transmit to it the difference of pressure. The apparatus consists of a mercury float chamber, in which rests a float of such variable cross-section that its movement is in direct ratio to the change of flow of water through the Venturi or Pitot tube or pipe. The movement of the float actuates a revolving shaft, to which is attached a hand pointing to a fixed dial with uniform graduations.

Attached to the shaft, and moving in proportion to its angular deflection, is a pen in contact with a rectangular chart wrapped on a revolving cylinder; also a traction wheel which passes over the face of a revolving disk, the wheel being geared to a train of wheels operating a series of small dials similar to that of a gas or water meter. The traction wheel is so constructed that its movement, while in contact with the face of the disk, is free from rubbing friction. Both the cylinder and the disk are operated by an 8-day marine clock.

This pen is of a special type, which can be operated for a long period with a single charge of ink, and is held in contact with the chart by means of a delicate spiral spring, whose tension is easily adjusted to produce the minimum necessary pressure against the chart.

It is evident that the movement of the traction wheel, as well as that of the pen, being in direct ratio to the angular deflection of the shaft, is in direct ratio to the movement of the float, and, therefore, to the flow of water through the pipes. As both the disk and chart cylinders are operated by the clock, their angular movements are equal for equivalent intervals of time.



TOP OF SIMPLEX METER REGISTER WITH GLASS DOME REMOVED

Charts are uniformly graduated in gallons per 24 hr. or pounds per hour, as desired, the range of flow dial, chart, chart recorder and total flow register all being enclosed in a dust-proof glass dome, which rests on a felt gasket, thus exposing the mechanism to view at all times.

WATER WAS TURNED through the Bear River plant of the Pacific Gas and Electric Co., recently, and current from this development, which has a present capacity of 33,000 hp., was delivered to the bay cities. The local offices of the company received word that the plant was working without a hitch and the dam appears to be water-tight. Future installations will raise the capacity of this development to 160,000 hp.

Gebhardt Steam Meter

STEAM APPLIANCE CO., CHICAGO

AS is shown in Fig. 1, this meter consists essentially of a Pitot tube and a water gage glass with special fittings so constructed that the condensation will collect in the glass. The height of the water column varies directly with the weight of steam flowing in the pipes.

Figure 2 shows the meter complete with pressure-gage chart and pointer. The chart is graduated to read pounds per hour and is read direct by turning it so that the given pressure is in line with the pointer, which is placed on a level with the water column.

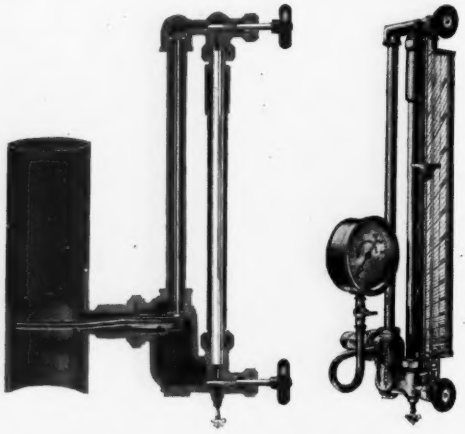


FIG. 1. SECTION SHOWING ARRANGEMENT OF PITOT TUBE AND METHOD OF ATTACHING METER

FIG. 2. METER FULLY EQUIPPED

The meter, which is attached to the pipe by means of a ¾-in. nipple, is adapted to pipes of any size and in any position. The only changes necessary for different pipe diameters are the inner tubes and charts, which can easily be replaced.

St. John Steam Meter

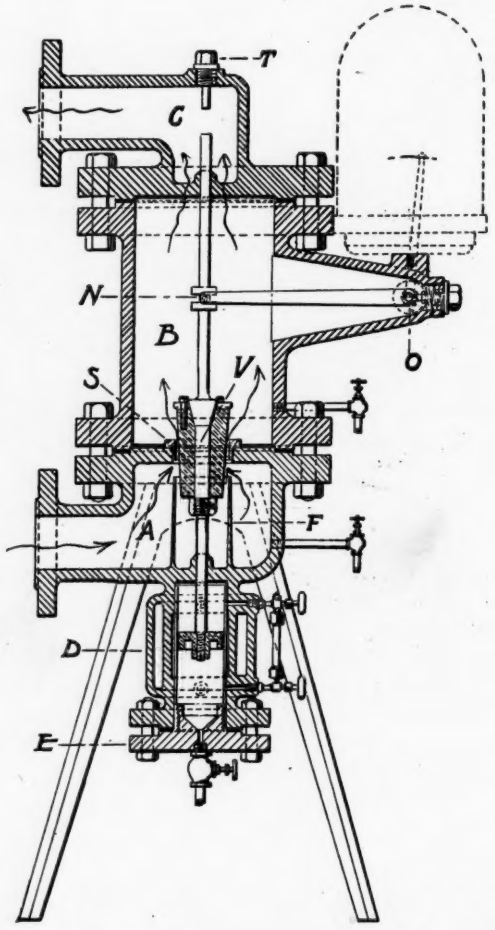
G. C. ST. JOHN, NEW YORK

THIS meter operates on the principle that with a uniform difference of pressure on 2 sides of an orifice, through which steam is flowing at a constant initial pressure, the quantity of steam passing bears a direct relation to the size of the orifice.

As shown by the section in the cut, S is a brass valve seat and V a brass valve, called the meter valve, having a tapered shank or plug carried on a spindle running in guides at the top and bottom. When in the lowest position, the tapered plug fits closely within the seat, upon which rests the lip of the valve, so that no steam can flow. As the meter-valve is raised, the opening between the seat and tapered plug increases from 0 to a maximum when the valve is in its highest position, the rate of increase depending upon the taper of the plug. Thus the area of the annular orifice varies as the plug rises or falls, which occurs as the flow of steam increases or decreases.

The weight of the meter-valve and spindle is such that the pressure beneath the valve in space A must be about 2 lb. greater than that in space B, in order to raise the valve off its seat and keep it floating in the current of steam. Since the weight of the valve remains constant, a difference of pressure on the 2 sides of the orifice of about 2 lb. per sq. in. is maintained, regardless of the position of the valve. The taper of the plug is such that the quantity of steam passing through the orifice is directly proportional to the rise of the meter valve.

With a lever turning about O as an axis and connected to the valve spindle at N, this motion of the valve is transferred to the recording arm outside the



SECTIONAL ELEVATION OF ST. JOHN STEAM METER, SHOWING MECHANISM

meter casing, which carries the brass pencil and pointer. By means of these, the rate of flow of steam in boiler horsepower may be read from the indicator dial at any instant, or recorded on the chart operated by a clock movement. It is necessary to steady the movement of the meter valve by cushioning with the dash-pot which, after steam is turned on the meter, always contains water of condensation.

Steam at any pressure and temperature may be measured by this meter. The quantity of steam flowing per hour per inch of height of steam line on the chart, as measured from the base line, is called the "rate" or "constant" of the meter. The rate furnished is for saturated steam at 100 lb. gage, but for any other pressure this rate must be multiplied by a factor corresponding with the steam pressure.

Worthington Hot-Water Meters

HENRY R. WORTHINGTON, NEW YORK

TWO distinct types of this meter are used for the measurement of boiler feed, the duplex piston meter and the turbine meter. The duplex piston meter is particularly adapted to the testing of boiler plants, and may also be used for continuous service on small-sized plants, not exceeding 200-hp. boilers. For the continuous measuring of large volumes of hot boiler feed-water under pressure, the turbine meter should be used.

As will be seen from Fig. 1, the duplex meter is practically the water end of a duplex, double-acting pump, having the cross-over valve motion in the bottom. The moving parts consist of 2 plungers and 2 slide valves, with a lever, which conveys the motion of the plungers to the recording mechanism. The ends of the cylinder are fitted with adjustable tappets, by means of which the length of the plunger stroke, and, consequently, the displacement per registration on the counter, may be altered. This provides a means of calibrating the meter for any service.

This meter is regularly made with the main casting of iron, galvanized and bronze lined, and the plungers of hard, close-grained cast iron, or of brass composition, as may be specified. This form of construction is offered for any working pressure up to 175 lb. per square inch, and any temperature up to 212 deg. F.

Hot-water test meters should be connected on a by-pass, so that the meter may be thrown in or out of service, as desired, without interrupting the flow of the water to the boilers, and may be calibrated under the actual running conditions without disturbing the piping.

The turbine meter, Fig. 2, is of the current, or velocity, type, designed to handle large volumes of water with minimum loss of pressure. The wheel is surrounded by a chamber of the volute pattern, providing at all points of the circumference the cross-sectional area necessary to handle the amount of water discharged by the wheel, without checking the speed of the water.

This meter is adapted to severe conditions of service on account of the absence of bearing and wearing surfaces, the only point of contact outside the clock gearing being the jeweled bearing which carries the vertical shaft and wheel. The wheel is double and water-balanced, eliminating end thrusts; consequently, the friction at this point is reduced to a minimum.

This wheel is of spun copper, making it impervious to the chemical action of boiler compounds, which are frequently pumped through with the feed-water. This meter is designed for any working pressure up to 250 lb. per sq. in., and any temperature up to 250 deg. F.

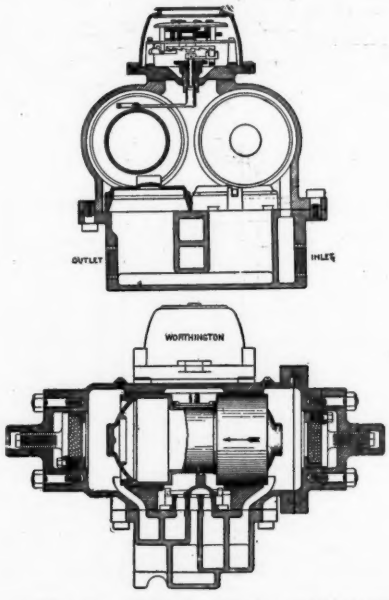


FIG. 1. DUPLEX PISTON HOT-WATER METER

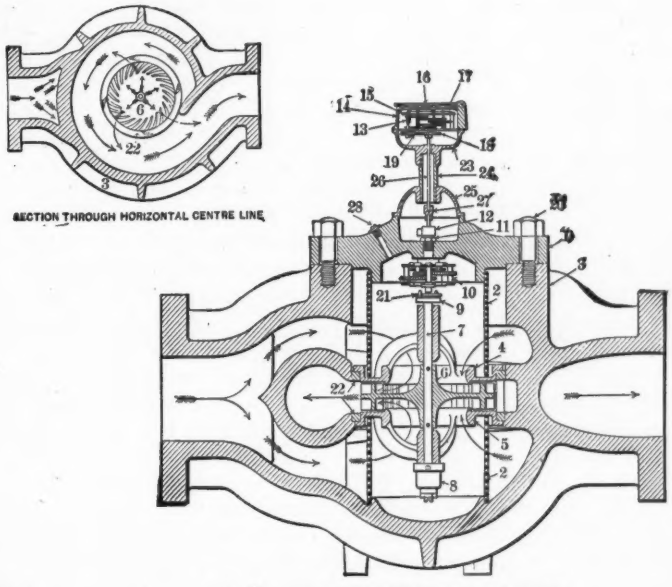


FIG. 2. TURBINE BOILER-FEED METER

FRANCHISE HAS BEEN GRANTED and plans are under way for a large hydro-electric plant at Center Village, N. Y., on the Susquehanna River, in the town of Colesville. Current will be distributed to Afton, Windsor and Colesville, and probably later to a larger territory. It is estimated that the development will cost $100,000, the prime movers in the enterprise being C. F. Wright and W. A. Bennett, of Susquehanna, Pa.

IN A RECENT letter regarding the use of soda ash and caustic soda to remove and prevent boiler scale, successful proportions were given by a chief engineer as 1½ to 1¾ lb. soda ash and 1/5 to ¼ lb. caustic soda per 1000 gal. feed water.

Calorimeters

PERCENTAGE OF MOISTURE IN STEAM DETERMINED BY SIMPLE DEVICES

STEAM—that is, not superheated—generally contains more or less moisture, which not only interferes with proper engine cylinder and turbine operation, but also causes a loss of heat utilized to raise the moisture from the temperature of the feed-water to the temperature of the steam. The general types of steam calorimeters, which are used to determine the quality of steam, are known as throttling or superheating calorimeters, separating calorimeters, and condensing calorimeters, or a combination from these.

Usually, in engineering practice, the throttling type is used on account of its simplicity and the reliable results obtained by its use. By means of a perforated nipple, an average sample of steam is taken from the steam pipe and allowed to expand through a small orifice, into a chamber open to the atmosphere. The heat liberated by the reduction in pressure serves, first, to evaporate any moisture present, and then to superheat the steam at the reduced pressure. From the observed pressure of the steam entering the instrument and its final pressure and temperature after expansion, the percentage of moisture in the sample can be readily calculated with the aid of steam tables. Unless the heat liberated by the pressure drop is sufficient to evaporate all the moisture in the steam and superheat the steam about 5 or 10 deg. F., there may be some doubt as to the accuracy of results. Moisture in excess of 2 per cent at comparatively low pressures, and in excess of 5 per cent at average boiler pressures, cannot be determined with the throttling calorimeter, but in general engineering practice, moisture determinations are within the limits of the throttling calorimeter.

For steam containing greater percentages of moisture the separating calorimeter is sometimes used. In this instrument the water is removed from the sample by mechanical separation, which depends for its action on changing abruptly the direction of wet steam moving with considerable velocity. The water thus removed is deposited in a vessel provided with a gage glass and graduated scale, from which the volume or weight of the separation may be determined, while the dry steam passes through an orifice into the atmosphere and is calculated according to Napier's rule or may be condensed and weighed. Owing to the difficulty of obtaining true samples of steam, in which the percentage of moisture is large, the determination of moisture is likely to be inaccurate.

In case the amount of moisture is large, the quality of the steam may be determined by condensing the sample in a known weight of water and observing the rise in temperature. The calorimeter operating on this principle is of the barrel or condensing type, and is little used, except where the steam supply is sufficiently large to permit the condensation of a comparatively large sample.

By means of a combined throttling and separating instrument, moisture of any degree may be determined. The percentage of moisture determined by separation and by throttling are found as when used separately, the sum of the two giving the total moisture content.

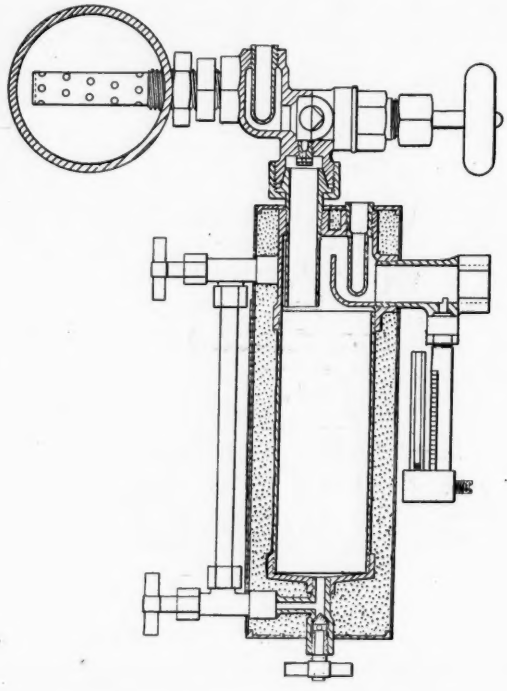
In steam calorimeter work, radiation losses are likely to affect the results unless all conditions leading to the main steam pipe and certain parts of the operation are protected thoroughly by a covering of good insulating material.

Ellison Throttling-Evaporating Calorimeter

LEWIS M. ELLISON, CHICAGO

AS shown by the sectional view, the essential parts of this instrument are as follows: A sampling nozzle, a special valve fitted with a throttling plug and thermometer well, a steam chamber and jacket, an outlet nozzle with thermometer well, a water glass and a mercury gage.

Since there are no pockets or upturns in the valve, steam entering the sampling pipe flows to the throttling plug at full pressure, where it is throttled into the chamber to nearly atmospheric pressure. It then flows



SECTIONAL ELEVATION OF THROTTLING-EVAPORATING CALORIMETER

down along one side of the chamber and up the other into the exhaust nozzle at the top. Moisture in excess of the capacity of the throttling process is separated in the chamber and re-evaporated by the superheated steam after a momentary period of excess, thus lowering the temperature at the outlet thermometer in direct proportion. The moisture in excess of both the throttling and evaporating processes, if any, collects and is measured in the water glass. Moisture carried in the upflow passes between the 2 thermometers, through a bath of superheated steam, where it is subjected to a highly effective

process of evaporation, thus forming a combined throttling, separating, and evaporating calorimeter in one chamber and in one simple instrument.

In both sides of the valve, which has a safe working pressure of about 300 lb., are 2 ¼-in. plugs, one for attaching a test gage for calibrating the thermometers in the thermometer well of the valve, and the other for checking steam gages used in tests. When in use, the valve and union below it are wrapped with tissue paper, which serves as a good nonconductor of heat.

Thermometer wells are made with thin walls of 30 per cent nickel steel, either oil or mercury being used for the thermometer bulb bath.

Four throttling plugs, which are also of 30 per cent nickel steel, are reamed to 1/16, 3/32, ⅛ and 5/32-in. orifices, an atomizer being located just below the orifice, where the steam strikes a flat surface, dividing into 4 streams, meeting and mixing below the plug.

Both the steam chamber and the jacket, which are 2 in. and 3 in. in diameter, respectively, are made of brass tubing, the space between them being filled with lampblack, which is a nonconductor.

Intimate contact of the steam with the thermometer well is effected by means of the baffle in the outlet nozzle, and condensation in the mercury gage is prevented from slushing back into the steam chamber under pressure pulsations.

With the exception of the lock nut and scale, the mercury gage is of 30 per cent nickel steel. The scale, which reads in 0.1 in., is graduated to compensate for the fall of mercury in the chamber, the static pressure tip in the nozzle compensating for the aspiring effect.

By means of the thermometer placed in the cup of the valve, the inlet temperature and corresponding pressure are determined, while with the aid of the thermometer and mercury gage at the outlet nozzle, the throttled pressure and degree of superheat are measured. In case of excess of moisture, the weight of the separation is indicated by the water glass on a scale graduated in 0.01 lb. on the basis of 212 deg. F. and a half-turn opening of the lower connection. From the data thus furnished, it is possible to calculate the per cent of moisture in any case.

Carpenter's Throttling Calorimeter

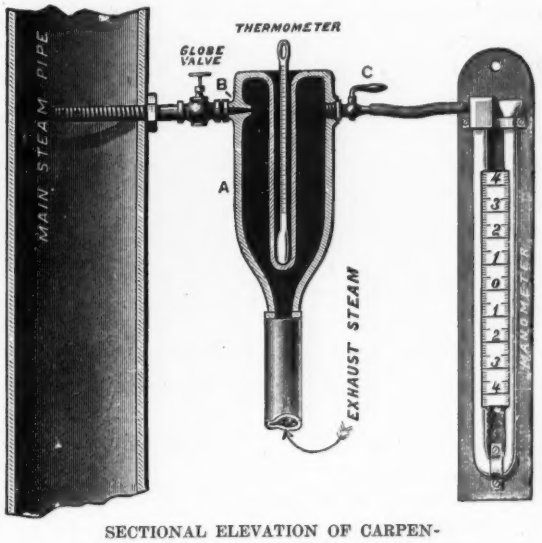
SCHAEFFER & BUDENBERG MFG. CO., BROOKLYN, N. Y.

THIS instrument, which is used to determine the amount of moisture in saturated steam, is shown in the illustration attached and ready for use. It consists of a vessel about 3 in. in diameter, to which steam is supplied through a tapering or converging orifice, and which contains a deep cup, into which a thermometer can be inserted for obtaining the temperature of the steam in the calorimeter.

Its accessories consist of a collecting nipple, which is screwed into the main steam pipe, a valve used for turning steam on or off to the calorimeter proper and a cock, to which is attached a U tube for measuring the pressure in the interior of the vessel.

The exhaust steam passes out at the bottom of the chamber and is conducted away in a hose or pipe, or is permitted to escape into the air, as is convenient.

The principle on which the throttling calorimeter operates is as follows: Some of the heat contained in high-pressure steam is liberated when the pressure is lowered, and that heat is utilized in evaporating any water the steam contains and in raising the temperature of the steam above that due to its pressure, provided that the moisture contained is not too great. If the steam contains more moisture than can be evaporated by the heat thus liberated, the throttling calorimeter cannot be used for determining the moisture in the steam. The limit of the instrument varies from about 2.3 per cent



SECTIONAL ELEVATION OF CARPENTER'S THROTTLING CALORIMETER

of moisture at 35 lb. pressure, to 7 per cent at 235 lb. gage pressure. These limits will, however, generally cover all steam pressures used for commercial purposes, and within these ranges the throttling calorimeter is a convenient and reliable instrument.

SHIPMENT OF valuable ores containing uranium and radium has been going on for the last 2 years from mines in Colorado and Utah, without the realization of the American public. Statistics furnished by the Bureau of Mines show that from these ores was obtained nearly 2½ times as much radium as from all other sources. The unfortunate part of the situation is that for shipment abroad, only ore carrying 2 per cent or more of uranium oxide pays for shipment; while in taking this from the mines, 5 times as much ore of slightly lower grade, which could be worked to advantage in this country, is thrown on the dump or left in the mines. Further, the ore that is sent abroad is worked up in foreign plants and the radium resulting can be made available for the use of American physicians and institutions only by purchase at almost prohibitive prices. Foreign governments have Radium Institutes for investigating and developing the use of radium in medical practice, and this is probably the explanation of the development and the manufacture of radium abroad and its lack of development here.

CONCENTRATION is the secret of strength.—Emerson

Isolated Power Plant Records

WHAT THE RECORDS SHOULD SHOW TO THE ENGINEER AND TO THE OWNER, A SYSTEM SUGGESTED, DETERMINATION OF UNIT COSTS

KNOWLEDGE has proved to be power in the power plant field as in all other fields of industrial endeavor. This is evidenced by the fact that the most successful engineer for a plant is the one who knows the most about that plant and uses that knowledge to the best advantage of the plant. First of all it is necessary to know the apparatus, every piece, every pipe line, every valve, every device and the uses to which it can be put. More than this, the weak points or failings of each machine should be learned by the operator. All this knowledge can be obtained by daily contact with the plant.

Aside from knowledge of apparatus and arrangement, there are the apparently unseen influences and conditions which may make towards success or failure and these should be sought out and developed or eliminated as need be for best economy.

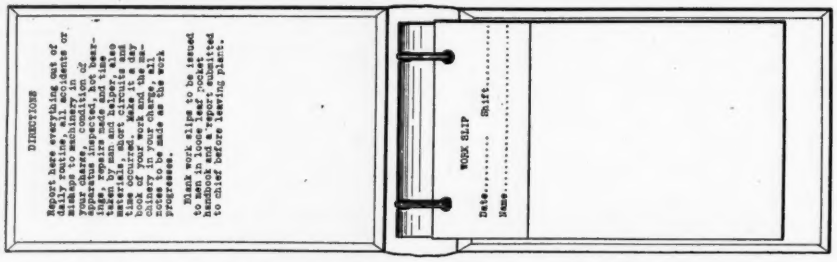

DIRECTIONS
Report here everything out of the ordinary, accidents or delays, also orders given mechanics or mechanic in your charge, condition of machinery in your charge, breakage, repairs made and time taken by man and helper, also material used. Write down time occupied each day on each piece of work and the machinery in your charge, all orders to be made as the work progresses.
Blank work slips to be issued to men in loose leaf pocket Handbook and a report submitted to chief before leaving plant.
WORK SLIP
Shift.....
Date.....
Name.....

FIG. 1. LOOSE-LEAF POCKET NOTE BOOK WITH FORM FOR DAILY REPORT

Aside from knowledge of apparatus and arrangement, there are the apparently unseen influences and conditions which may make towards success or failure and these should be sought out and developed or eliminated as need be for best economy.

The questions arise, how can this information best be obtained and preserved for the benefit of the plant? Should the information gathered be only sufficient to prove the success or failure of the plant as a whole or should it go to the very roots of the power plant and indicate the exact points where the equipment, arrangement or management is weak and subject to improvement?

As a rule, the owner of a plant wants the best results obtainable with the equipment at hand, he is not always interested in knowing that some piece of apparatus is less efficient than can be secured, provided the engineer's report shows an overall economy and service which cannot be secured from some other source. Consequently the engineer's monthly and yearly reports should show conclusively what service has been given by the power plant and its force, and the cost. Costs, however, should be so divided that each line of service is separated from the total and where possible the cost per unit determined so that a direct comparison can easily be made with prices quoted by outside concerns to the owner for like service.

For instance, the cost of electric service should be isolated from other costs and the price per kilowatt-hour which it has cost the owner should be clearly itemized.

COAL RECORD MONTH OF _____ 19__

DATE	TICKET NO.	KIND	KIND	KIND	DEALERS WEIGHT	CITY SCALE WEIGHT	DIFFERENCE IN WEIGHT		B.T.U. PER LB.	PERCENT ASH	PER CENT MOISTURE	PRICE PER TON	COST

FIG. 2. FORM FOR KEEPING COAL ACCOUNT

Cost of elevator service could be recorded per car mile; heating, per pound of steam condensed or cost per square foot of radiation per season; water, cost per 1000 gal. pumped; refrigeration, cost per equivalent ton of ice, etc., proportioning in each case the proper amount of labor and supplies. Such a report to the owner together with a general statement of conditions and reasons for variations from former reports is usually sufficient and conclusive.

To obtain such information is not always an easy matter and may necessitate the purchase of instruments and apparatus the value of which cannot always be seen by the owner, but by careful selection of instruments and a systematic routine for testing separate sections of the plant, the cost of these appliances need not reach an excessive amount.

Again, the engineer must, in order to secure best operation and economy, analyze each service given by the plant, also each transformation from coal to heat, heat to steam, steam to power, power to its various uses, etc. To do this records are absolutely essential, the extent to which they should be carried depends largely upon the size of the plant and the extent of the service rendered.

The system of records starts naturally with a daily log sheet which should contain hourly readings of the performance of the apparatus which would include pressures, temperatures, meter readings, coal and ash handled, time of starting and stopping, etc. If the plant is large, a log sheet may be kept for the different departments such as the boiler room, engine room, refrigerating machinery, elevators, etc. In addition to the log sheets a day book is convenient for making notations of repairs, deliveries of materials or work performed by the force outside of the regular operation.

From these records as a beginning, the engineer may build his entire record system. The daily log is summarized and entered upon the monthly report sheet which should be made out in duplicate, one for the engineer's files, and one for the superintendent or manager.

In order to get operating data down to a comparative basis, so that the performance of each piece of apparatus may be compared from month to month, what might be termed a ledger is most convenient. This may be kept in book form, or what in some cases is more convenient, a card file with a card for each important machine. On this card should be noted a brief description of the apparatus, its cost, when installed, manufacturer's guarantee of performance; following this each month, the hours or days of service, all repairs and their cost, and any data which may affect its efficiency or life.

Once a year an expense sheet should be made out for each service rendered. This can be accurately determined from the monthly reports or closely estimated where means for securing proper information are not available.

The System Detailed

Using the foregoing as an outline, the following system has been worked out for an isolated plant furnishing about all the services required of any plant. The forms can be modified to suit conditions and the system is planned to take as little of the chief engineer's time as possible, yet a careful study of the daily records and comparison with former results will keep him in the closest possible touch with the entire plant and the force.

BOILER ROOM DAILY REPORT. DATE_____

TIME	BOILERS B=BANKED F=FIRED 1	2	3	4	5	6	ST. GAGE PRES. LB.	DR. GAGE IN. OF WATER	TEMP. F.W. HEATER INLET	OUTLET	TEMP. HTR RETURNS	TEMP. FLUE GAS	TEMP. OUTSIDE ATMOS	LINE ST. ON HTR SYSTEM	READINGS CONDENSATION METER
7 A.M.															
8															
9															
10															
11															
12															
1 P.M.															
2															
3															
4															
5															
6															
7															
8															
9															
10															
11															
12															
1 A.M.															
2															
3															
4															
5															
6															
TOTALS OR AVER.															

	1ST SHIFT	2ND SHIFT	3RD SHIFT	TOTALS OR AVERAGES	REMARKS
COAL BURNED-LB.					
ASH REMOVED-LB.					
CITY WATER METER READING					
FEED WATER METER READING					
B. F. PUMPS STROKE RECORDER READINGS 1					
B. F. PUMPS STROKE RECORDER READINGS 2					
B. F. PUMPS STROKE RECORDER READINGS 3					
FLUE GAS ANAL. PERCENT CO_2 BEGINNING					
FLUE GAS ANAL. PERCENT CO_2 END					
FLUE GAS ANAL. PERCENT O BEGINNING					
FLUE GAS ANAL. PERCENT O END					
FLUE GAS ANAL. PERCENT CO BEGINNING					
FLUE GAS ANAL. PERCENT CO END					
STOKERS RUNNING HOURS					
COAL CONVEYOR RUNNING HOURS					
HOUSE PUMPS STROKE RECORDER READINGS 1					
HOUSE PUMPS STROKE RECORDER READINGS 2					
HOUSE PUMPS STROKE RECORDER READINGS 3					
SUPPLIES DRAWN					
CYLINDER OIL					
ENGINE OIL					
GREASE					
WASTE					
SUPPLIES ON HAND					
CYLINDER OIL					
ENGINE OIL					
GREASE					
WASTE					
BOILER COMPOUND					

1ST SHIFT_____ FIREMAN

2ND SHIFT_____ FIREMAN

3RD SHIFT_____ FIREMAN

FIG. 3. BLANK FORM FOR BOILER ROOM REPORT

Furnish each man held responsible for a section of the plant, repair work or any work which is under the direct supervision of the chief engineer with a loose-leaf notebook, pocket size. Inside the front cover may be pasted directions for making out the desired report of his work, such as:

"Report everything out of your daily routine, all accidents or mishaps to machinery in your charge, condition of apparatus inspected, hot bearings and how remedied, repairs made and time taken by you and helper and materials used, needed repairs, etc. Make a engineer. From these tickets the coal record is made as shown in Fig. 2. During delivery, samples are taken and delivered to a chemist for analysis, the B.t.u. per pound, per cent ash and moisture being the determinations made by the chemist.

ENGINE ROOM DAILY REPORT DATE_____

AMMETER READINGS								HOURS OF SERVICE									
TIME	1	2	3	4	5	6	TOTAL		1ST SHIFT STARTED	1ST SHIFT STOPPED	2ND SHIFT STARTED	2ND SHIFT STOPPED	3RD SHIFT STARTED	3RD SHIFT STOPPED	TOTAL HOURS ON	
7 A.M.								EL. GEN. UNIT NO. 1								
8								" " " " 2								
9								" " " " 3								
10								" " " " 4								
11								BALANCER NO. 1								
12								" 2								
1 P.M.								ELEV. PUMP ENG. NO. 1								
2								" " " " 2								
3								" " " " 3								
4								FIRE PUMP NO. 1								
5								" " " 2								
6								REFRIG. COMP.								
7								CIRC. PUMP NO. 1								
8								" " " 2								
9								DRINKING WATER FILTER								
10								VACUUM CLEANER								
11								PNEUMATIC TUBE								
12								AIR COMPRESSOR								
1 A.M.								EJECTORS								
2								EJECTOR AIR PUMP								
3								VENTILATING FAN								
4								CANS ICE								
5																
6																
TOTAL AMP. HR.																
TOTAL KW. HR.																

SUPPLIES								ELEVATORS							TRIPS	CAR MILES
SHIFT	CYL. OIL PINTS	ENG. OIL PINTS	GREASE POUNDS	WASTE POUNDS	PACKING POUNDS			ELEVATOR NO. 1								
1								" " 2								
2								" " 3								
3								" " 4								
								" " 5								
								" " 6								

1ST SHIFT_____ ENGINEER 2ND SHIFT_____ ENGINEER 3RD SHIFT_____ ENGINEER

FIG. 4. CONVENIENT FORM FOR ENGINEER'S DAILY REPORT

complete but concise daybook of your work and machinery in your charge. Each day, submit to the chief engineer before leaving the plant, the work slips, together with results of any tests made, indicator cards, boiler inspection report or other information desired by the chief engineer, all signed and dated."

Figure 3 is a form for boiler room report which is complete and needs little comment. It will be noted that for the boiler feed and house water pumps, space is provided for readings of the stroke counters; in case meters are provided for measuring these quantities their readings should be recorded in these lines. Where

MONTHLY REPORT MONTH OF_____ 19__

DATE	COAL				WATER							ELECTRIC CURRENT												ELEVATORS					HEATING					MISCELLANEOUS								EARNINGS OF FORCE					
	POUNDS DELIVERED	POUNDS USED	POUNDS ASHES REMOVED	TONS IN STORAGE	POUNDS ASHES REMOVED	CUT-OUTS OPENED	TOTAL GAL. WATER	HOUSE WATER METER READING	DISTILLED WATER METER READING	R.P. METER READING	S.B. WATER METER READING	S.B. FEED METER READING	HIGHEST AMPS.	LOWEST AMPS.	TOTAL OUTPUT KW. HR.	AVG. C.P. FOR HR.	TOTAL KW. FOR LIGHTS	TOTAL KW. FOR POWER	TOTAL KW. FOR HEATING	TOTAL KW. FOR ELEVATORS	TOTAL KW. FOR MISC.	AMPERES	TOTAL CAR MILES	PASSENGERS CARRIED	FREIGHT TONS	TOTAL HOURS	TOTAL CAR MILES	PASSENGERS CARRIED	FREIGHT TONS	TOTAL HOURS	NO. F.H. STEAM	RETURN STEAM	RETURN WATER LB.	HIGHEST TEMP.	LOWEST TEMP.	MEAN TEMP.	NO. OF SWEEPERS	HOURS SWEEPING	NO. OF CLEANERS	HOURS CLEANING	HOURS POLISHING TUBE	VERTICAL FEET	CYL. OIL PINTS	ENG. OIL PINTS	GREASE POUNDS	WASTE POUNDS	PACKING POUNDS	ELECT. LIGHT	ELECT. POWER	GAS WORK	OTHER WK.	MISC.	
1																																														
2																																														
3																																														
4																																														
5																																														
6																																														
7																																														
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30																																														
31																																														
TOTALS OR AVER.																																													

SERVICES RENDERED

ELECTRIC LIGHT AND POWER—COST PER KW. HR._____
ELEVATORS—COST PER CAR MILE_____
HEATING—COST PER 1000 LB. STEAM_____
ICE AND REFRIGERATION—COST PER TON_____
HOUSE WATER—COST PER 1000 GAL._____

OPERATING EXPENSE

SALARIES_____
COAL_____
WATER_____
ASH REMOVAL_____
SUPPLIES_____
REPAIRS AND MAINTENANCE_____
IMPROVEMENTS AND ADDITIONS_____
INTEREST ON INVESTMENT_____
TOTAL_____

CHIEF ENGINEER

FIG. 5. FORM FOR MONTHLY REPORT OF CHIEF ENGINEER

The chief then files these reports in chronological order and may have them bound each month or year as convenience may demand.

As coal is delivered to the plant, the dealer is required to send a duplicate ticket which is left with the chief

no meters are provided, the pumps should be calibrated and an estimate made of the amount of water handled each stroke, then by counting the strokes an estimate can be made of the water handled. This is, of course, not very accurate but will serve in making an estimate.

Space is also provided for recording the analysis of the flue gases. This analysis takes several minutes and for that reason is made only twice during each shift, which will give the chief engineer an idea of what kind of work the shift can do. A recording CO_2 meter would be more satisfactory, but is somewhat expensive.

Outside temperature, direction of wind and general weather conditions affect more or less the demand upon the plant for heat. These items can usually be obtained from the report of the weather bureau in daily papers and together with the weather forecast will aid the engineer in providing for predicted weather.

A test not often made is that of combustible in the ash, but as a guide to the efficiency of combustion this is quite as important as analyzing the flue gases.

Under the head of "Remarks" may be placed the time of blowing down, popping of safety valves, blowing of flues, etc.

The boiler room record should be kept by the head fireman of each shift or at least he should be held accountable for it and the results obtained.

For the engine room daily report, the form shown in Fig. 4, allows space for about all that is necessary for an isolated plant, the form can, of course, be extended to provide for hourly readings on each machine, but this may prove a useless burden upon the engineer.

ENGINE CARD

Engine No..... Maker.....
Name & Address

Type..... Size..... Speed..... Rating....hp.

Steam pressure.....

Guarantee of performance or test result. Steam cons. at ½ load.....

¾....., 1....., 1¼....., and 1½ load.....

Cost..... Date installed.....

(Record all extra work and repairs on this engine here and their cost including labor. Each month record total hours run and reduce to days of 24 hr.)

BOILER CARD

Boiler No..... Maker.....
Name & Address

Type..... Rating..... Heating surface.....

Grate area..... Make or type of furnace.....

Size drum..... Size tubes..... No. tubes.....

Thickness of shell..... Safe steam press.....

Superheat..... Cost..... Date installed.....

(Report all repair and maintenance work with cost. Hours in service during month. Date and result of inspection.)

FEED WATER HEATER

F.W.H. No..... Maker.....
Name & Address

Type..... Rating..... Heating surface or tray surface..... Size tubes or trays.....

Filtering material, kind and amount for each charge .....

..... Cost..... Date installed.....

(Repairs - Cleaning - Days in service - Average temperatures for month)

GENERATOR CARD

Generator No..... Maker.....
Name & Address

Type..... Rating ..... kw. .....Amp.

.....Volts a.c. d.c. ..... phase ..... cycles

.....r.p.m. Efficiency at different loads, ½..... ¾.....

1..... 1¼..... 1½..... Cost..... Date installed.....

(Report all repairs - hours run and kw.-hr. delivered in month.)

HEATING SYSTEM

Kind..... Sq. ft. radiation.....

Temperature maintained ..... Pressure.....

Equipment..... Pumps.....

Receiver..... Traps.....

B. P. Valve..... Meters.....

(Repairs, additions, lb. condensation, mean temp. for month., hr. exhaust steam, hr. live steam)

PUMP CARD

Pump No..... Used for..... Maker.....

..... Size cyl..... Suction
Name & Address

press..... Discharge press..... Steam press.....

Gal. per stroke at .....% slip ..... Cost.....

Date installed.....

(Record all repairs and hours run or number of strokes.)

ELEVATOR CARD

Elevator No..... Maker.....
Name & Address

Use (Freight or Passenger) Type..... Size cables....

..... Diameter..... Length..... Weight, Counter

Weight..... Safe load .....lb. or No. people..... Safe speed

..... Trips per mile..... Cost..... Date

installed.....

(Repairs - Inspections - Car miles.)

FIG. 6. CARDS FOR INDIVIDUAL APPA RATUS WITH DIRECTIONS FOR THEIR USE

In case, however, the engineer wishes to investigate the operation of any particular piece of apparatus, a separate form may be made and a record of performance kept as long as desired.

All the above reports are left with the chief engineer daily. Summing up the various items, he is able to make the daily notation on the monthly report sheet, Fig. 5. From the work slips, entry is made each day upon the card record of each machine which has been repaired or overhauled and the cost of labor and sup-

plies for each is noted. Where this work is done daily, the task is not great and affords an excellent opportunity for the study and comparison of upkeep costs. At the end of each month the time in operation should be entered as a credit to the apparatus.

On the monthly report sheet is a summary of expenses the amounts of which are obtained from the payroll and monthly report.

Division of Expenses

From tests of the engines the pounds steam per kilowatt-hour at different loads are determined. With this as a guide, by selecting the generators so as to handle the plant load at the most economical engine load, the average steam consumption per kilowatt-hour can be closely estimated. When the engine exhausts to atmosphere or a condenser, the generators should be charged with this amount of steam. In a similar manner the steam required per car mile of the elevators can be estimated and the elevators charged with the amount they use. In like manner all steam engines should be charged with the amount of steam they use. This does not apply to the auxiliaries but gives a means for proportioning the steam generated among the power services rendered.

For example, suppose we determine that the steam per kilowatt-hour is 30 lb., per car mile, 130 lb. From the daily log we learn that 6000 kw-hr. were delivered, also that the elevators traveled 320 car miles. Then $6000 \times 30 = 180{,}000$ lb. steam chargeable to the generators, and $320 \times 130 = 41{,}600$ lb. to the elevators, so that the total expense in the boiler room would be

$$\frac{180{,}000}{221{,}600} = 0.812+$$

chargeable in the proportion given above, that is——— to the electric system and .0188 to the elevators.

When exhaust is used for heating, the just method would be to credit the steam machinery exhausting into the heating system with the B.t.u. used in the radiators; for this process some means of determining, or at least estimating, the amount of condensation returned is necessary.

To illustrate by means of an example: The total heat of steam at 125 lb. gage is 1192.2 B.t.u. and if exhausted to the heating system at 1 lb. gage, each pound has 1151.6 B.t.u., so that for each pound of condensation returned the steam engines should be credited with

$$\frac{1151.6 - 168}{1192.2 - 168}$$

or 0.958 lb. steam, 200 deg. being assumed as the temperature of the return water.

This applies when exhaust only is used, if, in addition to the exhaust, live steam is used the engineer should charge the boiler room expense to the various steam users in proportion to the B.t.u. used and wasted by each. The proportion of the heat of the steam which has been used in the heating system assuming dry steam at the exhaust of the engines, averages 96 per cent.

To proportion the boiler room expense when exhaust steam only is used for heating, make an estimate of amount of steam used in the power units as determined from the tests recorded on the various cards. Multiply the pounds of condensed exhaust returned by 0.96, the result will be the equivalent pounds of steam used for heating. Subtract this last result from the estimated pounds steam used by the power units and the remainder will be the pounds chargeable to the engines.

When, in addition to all the exhaust steam, live steam is reduced in pressure and fed to the heating system, the steam used by the engines is estimated as before and is multiplied by 0.04 (1.00 — 0.96); this gives the pounds chargeable to the engines. Subtract this quantity from the pounds of returns as metered and the remainder will be the steam chargeable to the heating system. The boiler room expense should then be divided in proportion to the amounts used as calculated above.

This method does not take into separate account the steam used in the auxiliaries which exhaust into the feedwater heater but since these all come in under boiler room expense and are as necessary to one part of the plant as the other, it is fair to divide this expense in proportion to the steam used.

Steam used by the various engines and pumps should be measured periodically by a steam-flow meter which will give a check on the operation and aid in proportioning the expenses of each unit.

Where graphic recording gages or meters are used, provision should be made for filing the records with the daily report of the boiler room or engine room as the case may be.

As an aid to the engineer, there is no part of the system of records which will point out more clearly changes in operating conditions than curves such as variation in coal consumption, oil used, temperature, elevator service, power generated, etc. There is no limit to which these may be carried, but a little study of the equipment of the plant will usually indicate what curves should be kept regularly and if it is desired to investigate the operation of any particular engine, machine or system, curves can be drawn for a time until the desired information is obtained.

There are no producing nickel mines in the United States. The output of nickel from domestic ores is merely a byproduct from electrolytes of the copper refineries. Salts and metal equivalent to 328 short tons of metallic nickel were saved in domestic refineries in 1912, from both foreign and domestic ores. Nickel ore "imported" for consumption, is mostly from the Canadian deposits.

By a court decision rendered on Nov. 14, 1913, in the case of the United States vs. Utah Power and Light Co., it is established that power companies cannot secure rights of way across national forests without complying with the regulations of the Secretary of Agriculture. The court decided that Congress has assumed complete control of the water-power question, so far as public lands are affected, and a state cannot interfere with this constitutional power; where state laws conflict with the acts of Congress in respect to public lands controlled by the nation, Congress has final jurisdiction and its provisions are binding as to the rights of those who acquire or use the lands.

Cost Keeping In The Power Plant

ITEMS OF EXPENSE AND THEIR RELATION TO OTHER PARTS OF THE PLANT. TAKING CARE OF FIXED CHARGES. OUTLINE FOR A SYSTEM OF RECORDS. BY STERLING H. BUNNELL*

THE purpose of keeping records of cost is to be able to make comparisons. Power today may cost less, or more, than on the same date last year; the cost system should tell which. The central station may offer to sell power at a low figure, and only cost records can show whether it is more profitable to run the engines or shut down. Electric elevators in one building may operate at less expense than hydraulic elevators in another. Even the engineer himself wants accurate records to show that the cost of power under his management is creditably low for the class of equipment under his charge.

Fortunately for the engineer, it does not need a force of bookkeepers to operate a cost system in the power plant. The regular log, properly amplified and kept up, provides the data necessary for the calculations. Fuel, water, supplies and labor are the items of outlay; mechanical work, electric current, and special service (as the furnishing of compressed air) are the returns. The cost-keeping problem is the correct division of the various items of outlay between the various items of output which they produce. To some extent this can be done directly, as by charging the firemen to the division of steam production, and the anhydrous ammonia to the ice machine operation. Some items, however, cannot be charged wholly into any one division as they are paid for, and these must be split up on some proper basis. It will be necessary, therefore, to take up each of the expense items of the power plant, and see what is its relation to the cost of power.

DIAGRAM OF POWER PLANT COST

ON THE accompanying diagram, the various items which go to make up the cost of power are set down in order. Each group framed in a border line belongs to a single convenient subdivision of power plant operation cost. The first group, at the left of the diagram, is that belonging to the cost of operating the boilers. The output of the boilers is steam, which is piped to various points of consumption, as heaters, engines and pumps.

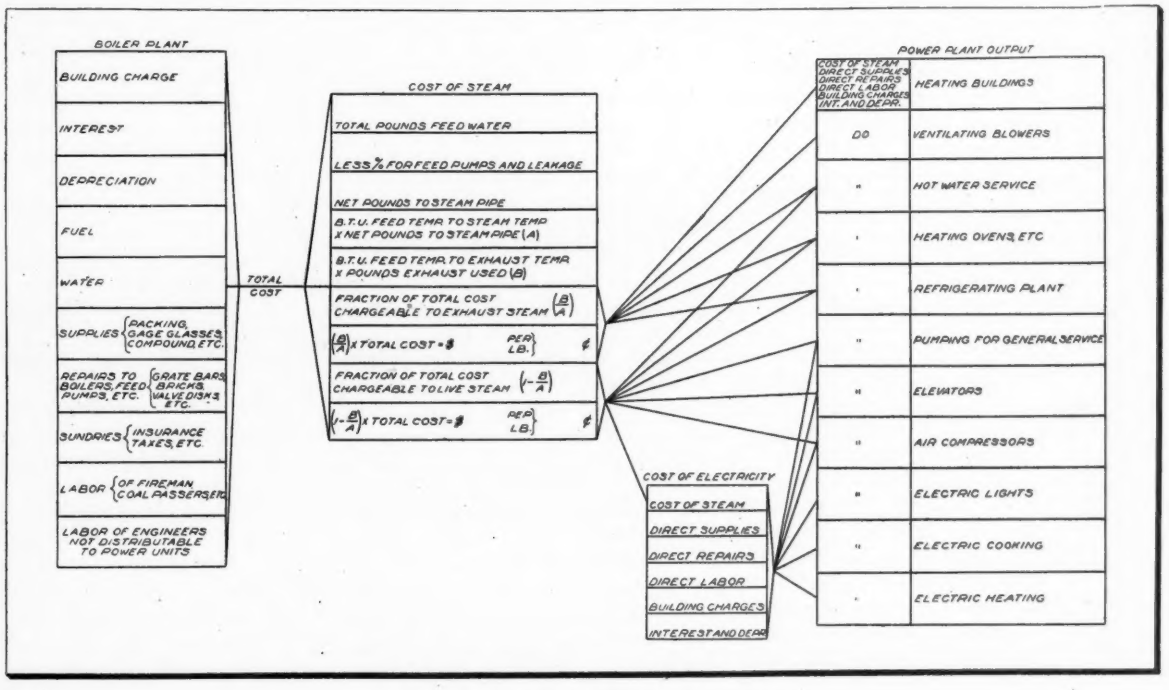
BOILER PLANT
BUILDING CHARGE
INTEREST
DEPRECIATION
FUEL
WATER
SUPPLIES {PACKING, GAGE GLASSES, COMPOUND, ETC.
REPAIRS TO BOILERS, FEED PUMPS, ETC. {GRATE BARS, BRICKS, VALVE DISKS, ETC.
SUNDRIES {INSURANCE TAXES, ETC.
LABOR {OF FIREMAN COAL PASSERS, ETC.
LABOR OF ENGINEERS NOT DISTRIBUTABLE TO POWER UNITS
TOTAL COST
COST OF STEAM
TOTAL POUNDS FEED WATER
LESS % FOR FEED PUMPS AND LEAKAGE
NET POUNDS TO STEAM PIPE
B.T.U. FEED TEMP. TO STEAM TEMP X NET POUNDS TO STEAM PIPE (A)
B.T.U. FEED TEMP. TO EXHAUST TEMP X POUNDS EXHAUST USED (B)
FRACTION OF TOTAL COST CHARGEABLE TO EXHAUST STEAM (B/A)
(B/A) X TOTAL COST = $ PER LB. ¢
FRACTION OF TOTAL COST CHARGEABLE TO LIVE STEAM (1 - B/A)
(1 - B/A) X TOTAL COST = $ PER LB. ¢
POWER PLANT OUTPUT
COST OF STEAM, DIRECT SUPPLIES, DIRECT REPAIRS, DIRECT LABOR, BUILDING CHARGES, INT. AND DEPR.
HEATING BUILDINGS
DO VENTILATING BLOWERS
" HOT WATER SERVICE
" HEATING OVENS, ETC.
" REFRIGERATING PLANT
" PUMPING FOR GENERAL SERVICE
" ELEVATORS
" AIR COMPRESSORS
" ELECTRIC LIGHTS
" ELECTRIC COOKING
" ELECTRIC HEATING
COST OF ELECTRICITY
COST OF STEAM
DIRECT SUPPLIES
DIRECT REPAIRS
DIRECT LABOR
BUILDING CHARGES
INTEREST AND DEPR.

FIG. 1. POWER PLANT COST DIAGRAM

The production of steam costs money, which cost can be stated in cents per hundred pounds. Each user of steam must therefore be charged with the cost of producing the quantity it uses. The entire operation cost of the boiler may thus be charged off in suitable portions toward the operating cost of each pump, engine and heater.

This relation is shown in the diagram by lines radiating from the points where the cost of steam is computed, to the groups of cost items making up the expense of operating the pumps, engines and other units. One of the most important steam users is the engine and generator equipment, which takes in pounds of steam and turns out kilowatts of current. Here again the

*Long experience in design, construction and management of power plants and machinery have given Mr. Bunnell complete familiarity with all phases of the field. His work has covered steam engines, boilers and specialties, pumping machinery, refrigerating plants, and special machines. He has made special study of cost systems and is a recognized authority on this subject.

entire cost of the operation is to be divided up among the various motors in proportion to the kilowatts used by each. The diagram shows this subdivision also by lines radiating from the electric generator cost group to the group giving the cost of each principal user of electric current.

Study of the diagram will show the purpose of each of the radiating lines. Some of these show 2 possible ways of applying power. Pumping, for instance, may be done by steam direct, or by electric current from the generators. Refrigeration may be done by engines driven by boiler steam, or by absorption apparatus heated by exhaust steam. The principal possibilities of this kind are shown by appropriate lines in the diagram, each line pointing out a possible direction in which an item of cost may be instrumental in the making up of another group of cost accounts.

Three classes of cost items may be observed in the various groups. The most obvious class is the direct cost made up of such items as coal, supplies and fireman's labor. The next is the indirect cost, made up of items like oil, engineers' labor, and other things which are not easy to divide up against the various machines and motors. Thus, oil in a single can may go into the bearings of all sorts of machines in quantities too small to charge up separately; and good engineers keep such close watch on everything about the plant that on many days no single hour's time can properly be charged to any one machine. The third class of cost items is that of fixed charges, such as the fair rental value of the space occupied by the plant, and the allowance for laying up enough money to buy a new turbine by the time the engine in use is worn out.

Many direct-cost items are paid for at regular intervals, as fuel bills and pay-rolls. These can easily be split up as necessary, as by weighing or measuring fuel, and dividing up labor cost according to time sheets kept for each man. Other items may be made up by charging the cost of each gallon of cylinder oil or pound of packing as it is taken from the stock-room, to the account of the particular division of the plant where it is to be used. The rest will be taken from bills for pieces ordered for repairs, or other articles purchased especially for direct use on some machine or device. By keeping a simple cost sheet for each division of the power plant, the direct items can be charged up as they occur, just as a merchant charges each article delivered from his store, against the particular customer who purchased it.

Indirect cost items must be split up in some way among the several divisions to which they seem to belong. One way to do this is by judgment, as when an engineer decides that ¼ of his time on the average is spent in caring for the main engines, ½ on the pumps, and the remainder on the electric lighting system, and divides up his weekly salary in these fractions among the 4 accounts. Another way is by percentage, as when the cost of lubricating oil is divided among engines in proportion to their horsepower; or the salary of a superintendent, and the expenses of his office force, amounting to 10 per cent of the pay-roll of engineers and firemen, is covered by charging an additional item of 10 per cent of the cost of labor in each department. All indirect charges must be noted and covered by making proper entries, on some such apparently reasonable basis, on the cost sheets of each division of the power plant. The entries must be made regularly, each day, week or month, according to the period chosen for making up the cost of the power plant operation.

Interest and Depreciation

The 2 classes of cost items just considered cover all the amounts which are paid by check or cash against receiving slips or time-sheets, and as they form practically all of the "operating cost," might therefore seem to comprise the entire cost of keeping the plant in operation indefinitely. But back of the plant equipment, there was somebody who put up the money to buy the boilers and engines, purchase the land, construct the buildings, and erect the whole into a working plant. The owner of the plant is entitled to receive interest on his investment, and more than that, he has the right to demand his money back in full at some definite time, just as if he had loaned the same amount to a friend for use in business.

The first year after the plant was started, it was "as good as new," so that it could almost be sold to another owner for enough to pay back the man who first provided it. The second year the plant had begun to wear a little, and was not quite so good; that is to say, it had "depreciated" further. Each year, the plant proceeds on its way toward its final graveyard—the scrap heap; and each year the wise operating man will charge unto his cost of power, a sum sufficient to provide for repairs and to make up for the further loss in value, for no repairs to an old machine can ever make it a new one.

Interest on amounts invested in standard machinery, like power equipment, forming part of the plant of a large building, railway or works, may be taken at 5 per cent. Depreciation is figured as if the sum of money set aside for the purpose each year, were invested at interest (like building and loan installments) until the total amount in the fund should make up the exact original value of the plant. If this were actually done, and a sum taken from the cash receipts of the business served by the power plant and put in a bank, the bank account would be a "sinking fund." Practically, the depreciation charge in a small plant is not paid over at all, but remains in hand as an apparent profit in the power plant account, to be transferred at the end of the year to the general depreciation account of the business. Assuming that the concern should pay 5 per cent for keeping and using the depreciation allowance, just as a bank would do, the amount to put aside to make up the value of the plant in 15 yr. is less than 1/20 of the first cost, or 5 per cent a year, and, with interest at 5 per cent, the total interest and depreciation allowance can be covered by charging 10 per cent of the cost of the plant into the yearly cost of power.

If the power plant has its own buildings, their value may be included with the value of the equipment in the cost of power, with sufficient accuracy for the engineer's purposes, though an accountant would analyze the situation more carefully, and probably decide on different rates of depreciation for buildings, boilers, engines and all the rest; 15 yr., however, seems a fair average for all. If the power plant occupies only part of a large building, a rental value should be set on the space occupied, and that value charged into the cost of operation. In general, rental values are based on building costs and expense of upkeep, and may be set so as to make a total return of 5 per cent annually on the whole value of

land and building, which is a minimum standard; or on a larger scale up to 10 per cent or even more. If the power plant in a valuable building occupies space which might just as well be used for something that would bring in money, that fact should be considered, and the rental value of the space set higher accordingly.

Every item of the equipment under the engineer's charge has its own proper interest, depreciation and building space charges, and these should be computed and added as part of the cost of service wherever the whole cost is wanted. This is evidently the case with the boiler plant, for part of the cost of steam is the fixed charge belonging to the boiler equipment. Taking an instance at the other end of the line, the total cost of operating an electrically driven compressor for cash carriers in a large store, includes the fixed charges belonging to the motor and compressor and space occupied; but the cost of power alone would be in cents per kilo-

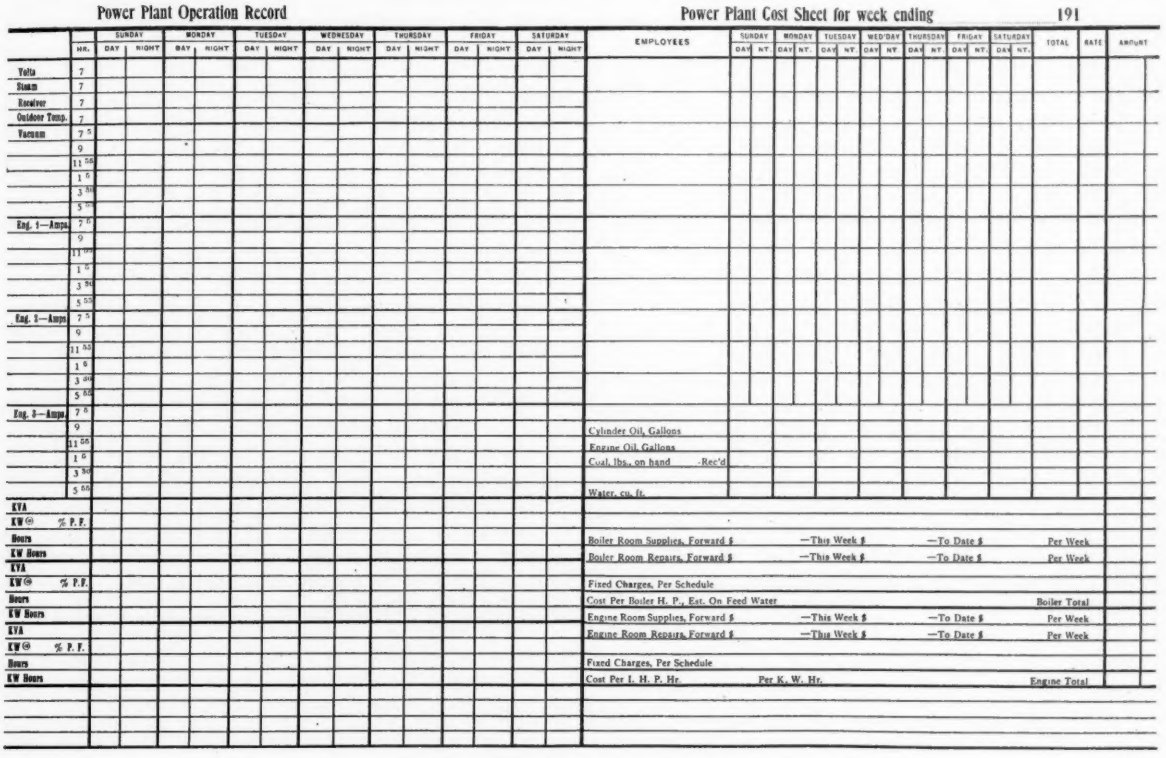

FIG. 2. RECORD SHEET USED IN FACTORY POWER PLANT

watt-hour as figured at the generator or switchboard, and would include only the fixed charges of the machinery up to and including the switchboard.

Fixed charges are figured by accountants on an annual basis, but for cost-keeping purposes should be divided by 12, or 52, and used as monthly, or weekly rates respectively.

Starting a Record

In starting a system of accounts in a power plant, the first step after deciding how many subdivisions of the plant cost will be useful for comparisons, is to ascertain the value of the equipment corresponding to each subdivision, and the rental value of the space occupied, and compute the fixed charges belonging to each subdivision in which total cost of operation, not merely cost of steam or electric current, is wanted. Thereafter in each month's or week's account, the last item to be set down is the regular fixed charge.

For the practical operation of a system of power plant cost accounts, return to the diagram and observe what quantities must be weighed, counted, timed or otherwise measured. First, the cost of steam is to be ascertained. The three items first under the head of "Boiler Plant" are building charge, interest and depreciation; these will be computed once for all in the form of a weekly installment, to be set down last in the boiler plant account for the week. Fuel, the next, will naturally be weighed as used. If, in a small plant, the owner will not provide the necessary scales, a makeshift can be used, which is to separate the weighed wagon loads or carloads of coal as received, and check the week's guess against the apparent fractions of loads on hand at the beginning and end of the week. Water, if purchased, should be metered for cost; but in any event, the quantity of feed-water pumped to boilers is of great interest, so that a meter is almost indispensable. Supplies should be kept in stock-room, or in a closet at least, and charged on the boiler plant account at their actual value on the dates they are taken out for use.

The next 2 items, Repairs and Sundries, have a troublesome way of coming in bunches, and a big repair bill in a single week is obviously not due to the particular week's operation, but rather to the operation of a long period previous. The best way to treat repairs is to average the year's probable total over the whole 52 weeks; but if the estimate is too uncertain, a makeshift is to spread each repair bill of any great amount over 5

or 10 weeks following, by charging it by installments 1/5 or 1/10 each week until the whole is made up.

Labor is easily provided for, because a time-book must be kept for pay-roll purposes, and so the hours of each man directly employed on definite work about the plant can be entered and known. At the end of the week the number of hours on work belonging to each subdivision of the power plant accounts can be totaled and the value at the wages-rate paid can be charged. The sum of the various charges will equal the total amount of the pay-roll, if the figuring is done correctly.

For the labor cost of those employes whose time cannot be charged hour by hour to this or that work, an approximation can be made by studying an average day's work and dividing the wages into regular fractions accordingly, 1/5 to one account, 2/5 to another, and so disposing of all. These divisions can be revised from time to time, or each week if it seems best.

Separating Steam Costs

In the ways described the week's cost is ascertained, entered in a simple account book, and totaled. The sum, in dollars, represents the cost of steam for the week. To convert it to cents per pound, the quantity of steam produced must be determined. The best way is by measuring the feed-water, and keeping a daily or hourly log of the meter readings as a check on the continuing accuracy of the meter. The steam used in the plant is in most cases of 2 kinds, high pressure and low pressure (or exhaust), and each has a value.

Exhaust steam is a byproduct or recovered waste, worth something, and its value is a credit against the whole cost of producing live steam. There is generally no competition from central stations with exhaust steam for heating purposes, so that the heating steam is indispensable and is worth its full cost in coal. The cost of the extra coal, etc., necessary to turn low pressure heating steam into high pressure power steam is in direct competition with central station power, and its net amount is important to know. The basis of division of the cost between these 2 steam services is given in the diagram as the relative heat units carried by live and exhaust steam above the feed temperature.

Under "Cost of Steam," therefore, is set down, first, the total pounds of water fed to the boilers, and next, the amount which passes through feed pumps and leaks and does not reach the steam pipe to the engines. The balance is the amount of steam delivered for use. From the steam tables, the heat units carried by steam at boiler pressure in excess of the heat units in the feed-water at its temperature when received by the plant, can be taken; also the heat units in exhaust steam in excess of the heat units in the feed-water.

Multiplying the 2 quantities of heat by the pounds of steam at the corresponding pressures, taking care to allow only for such part of the exhaust as is steam and not water, usually not over 85 per cent, the quantities of heat "A" and "B" are obtained as carried by the live and exhaust steam respectively. The total cost of the steam is now multiplied by the fraction $\frac{B}{A}$ for the cost of the exhaust steam, and the balance of the total cost is the cost of the live steam. Dividing these amounts by the quantities in pounds of the corresponding pressures of steam, the costs of steam in cents per pound is found.

The next problem is to find where the steam goes and in what quantities it is used. If steam meters were only as cheap and reasonably reliable as water meters, or ammeters, the determination would be easy. But in the absence of steam meters, approximations must serve. For machines using live steam direct, such as engines and pumps, indicator cards may be taken, and the steam consumption estimated on the basis of the probable steam consumption per horsepower as shown by the indicator cards, taken in connection with the known character of the engine or pump. Thus, a large steam pump showing an indicator card of 30 indicated horsepower might be estimated on a basis of 150 lb. of steam per horsepower-hour, or 4500 lb. of steam per hour total consumption. For heating apparatus, the condensation can sometimes be caught and measured, or if this is impossible, an approximation might be made by estimating the quantity of steam which should be condensed by the heating surface under known conditions. For machinery driven by shafting and belt, the horsepower required by each machine can rarely be obtained by a dynamometer, but approximations can be made by judgment based on the size of the machine, its speed, and other conditions. All estimates of power used, whether in the form of mechanical power derived from the engine through shafting and belts, or direct steam in cylinders of engines and pumps, or live steam condensed in heaters, should be converted to a common basis of pounds of steam per hour, and the total number compared with the net amount of steam already calculated to be fed to the steam main per hour. If a large discrepancy is shown, the estimates must be modified by good judgment, and the process repeated until the engineer is satisfied that he has fairly accounted for the total amount of steam delivered from the boilers to the main steam line. The quantity of exhaust steam used for heating and other purposes should be measured or estimated, and checked against the best evidence possible, which may be in the form of the total condensation returned to the boilers, or a special test of condensation returned from various parts of the plant, or the probable quantity of exhaust steam delivered by engines and pumps, based on their probable steam consumption and allowance for the amount of steam condensed in passing through cylinders.

Detailed estimates and totals made in this way are naturally subject to inaccuracy, and it is not to be considered that any such process can compare in precision with the direct use of meters, or better, the carrying out of special tests. Meters and special tests cannot, however, always be obtained, and a considerable measure of precision can be secured by an experienced engineer of good judgment, estimating the steam consumption, or the horsepower consumption, of each piece of apparatus or section of the plant, and comparing his best estimates, backed by measurement wherever possible, with the total steam consumption, to indicate whether the separate estimates are on the average too high or too low.

Having the number of horsepower-hours used by each section of the plant, and the steam per horsepower-hour, corresponding to each of these, the quantities of steam for each section can be computed; or the quantities of steam may be estimated direct if preferable. The quantities of steam used during the entire accounting period

of a week or a month as may be chosen, multiplied by the cost of the steam per pound, give the steam costs for each subdivision of the power plant operation. If the horsepower estimates are based on the probable power consumption of machine tools for instance, or of departments containing many machine tools, they must include the horsepower lost on the way from the engine to the machines or departments, by shafting and belting losses, if the totals of these estimated figures are to be compared with the total engine horsepower. Thus, if one of the power plant cost accounts is to cover the cost of power delivered to Department "A" of the factory containing say 35 machines using a total of 110 hp. on the average, this 110 hp. is supposed to include the losses by line shaft and belts between the engine and the machines. If preferred, the line shaft losses can be estimated separately; as would be the case if it were found that the machines themselves used only 90 hp., and the remaining 20 hp. were consumed by the shafting and belts between the engine and machines.

The important thing is to establish a common basis applying to all the factory, and not to compare the horsepower taken from the engine in the case of one department, with the horsepower used in the department machinery only in the case of another. The simplest way to avoid confusion is to convert all figures into terms of pounds of steam per hour used from the main steam pipe.

The principal steam user is generally the electric generating set. In the diagram, the cost of steam, supplies, repairs, labor and the fixed charges are shown as making up the cost of operating the generating units. Wattmeter readings, or ammeter and voltmeter readings, are to be taken to give the output of the generators. By dividing the total kw.-hr. of the week's run, into the operating cost of the generating units, the cost of current per kw.-hr. is obtained. By similar meter readings, the current consumption of lights, motors, and other users is obtained, and so the cost of current taken by each portion of the plant is computed. The sum of the amounts charged to the various accounts of the devices consuming electricity must be equal to the total cost of generating the electricity. The sum of the amounts charged to the account of apparatus using exhaust steam must equal the total cost value of the exhaust steam used; and the sum of the amounts charged for live steam, together with the value of the exhaust steam used, must make up an amount equal to the total cost of boiler plant operation.

The form entitled "Power Plant Operation Record" was devised to bring the daily and weekly summaries of operating details of a factory power plant, on a single sheet of paper. The load was quite steady, so the readings taken shortly after starting, in mid-session and shortly before stopping, gave a reasonably accurate record. The corresponding k.v.a. amounts were converted to kw. and kw.-hr., and the latter totaled. By providing 3 spans it was possible to compute 3 average loads for the proper number of hours each continued, and so provide for changes due to shutting down departments. The time-sheets for the plant labor follows, and lines for supply and repair costs. Finally, the total boiler plant cost and electric current cost are arranged for. In this plant, all the steam was used in the engines, so that the cost of steam per pound was not needed or found.

For more extensive plants, such as are found in most city buildings, the best form of record is an account book with reasonably wide pages, each with a number of columns. These are sold by stationers as "figuring books." With a volume assigned to each plant subdivision, a pay-roll can be divided up on a single line across the page, the amounts being set down in the proper columns. All items of expense are entered in the order in which they occur, the amounts in the proper columns. At the end of each week, a line drawn across the page serves to foot the columns and so determine the week's total expenditures under each head.

Analysis of Plant Costs

Using Power Plant Records to Determine the Financial Standing of the Plant and Where it Can be Raised. By E. C. Hitze*

IF one were to visit a power plant, of even moderate pretentions, be it industrial or otherwise, he would as a matter of course, find an engineer's log—a record of the hourly prevailing conditions, supplemented by the notes of all unusual events as they occur. In short, it is the operating history of the station.

But the real log of a power plant is written in dollars and cents and when properly kept, it tells the financial story as clearly, as concisely, and as simply as the regular log tells the operating story. (I met an engineer a few weeks ago who was operating a 1000-kw. industrial plant, and he was grievously worrying lest a central station in his city should supplant him. But I soon discovered that had he spent one-half as much time learning the significance of such a log as he did "cussing" the central station, the central station would have been worrying, and not he.)

Importance of Cost Analysis

This financial log, or analysis as it is commonly called, shows the input of money into each department; the relative cost of each department; a month-by-month comparison of the same department; and the running costs per unit of energy output. To be sure, the expenditures, or a greater part of them, are directly related to factors of operation which are more or less within the control of the operator, consequently a share of these factors is as necessary for record as the actual expenses and such items must be understood as included in a cost analysis. With such comparisons, the engi-

*With a training in engineering, received at Purdue University, Mr. Hitze began his practical work in an oil refinery on installation of refining machinery and later in design and superintending the operation of the power installation of the plant. Similar work with the Indiana Steel Co. was followed by 2 yr. as assistant engineer in large central stations, where he was in charge of comparison and analysis of records of operation and making tests of the machinery of the plant. His present work is the designing of steam specialties.

neer at all times is master of the situation; if economies are produced he knows by whom; if costs increase, he knows whom to hold responsible—this, of course, pertains to the larger stations. In the smaller plant, with few or no department heads, the same holds true, nevertheless, except that the engineer accounts to himself, not forgetting, "to thine own self be true."

It seems rather odd that in the larger plants where such systems are expensive, and laborious to maintain, they are kept up to the minute, so to speak, and extended in every direction; while in the small plant, where it should be comparatively simple matter, too often the operator is satisfied to know that "last year waste cost so much, oil so much, coal so much, etc." Unfortunately, this operator often deceives himself, as the following incident illustrates. An engineer of an industrial plant

NO.	ACCOUNT	JANUARY 1913	JANUARY 1914	FEBRUARY 1913	FEBRUARY 1914	MA 191	BER 1914	AVERAGE 1913	AVERAGE 1914
1	SUPERINTENDENCE	325	373						
2	ENGINE ROOM LABOR	400	380						
3	BOILER " "	1385	1840						
4	ELECTRICAL "	300	325						
5	MISCELLANEOUS	200	210						
6	TOTAL LABOR	2550	2530						
7	COST OF FUEL	10,026	10,915						
8	ENGINE ROOM SUPPLIES								
9	BOILER "								
10	LUBRICANTS								
11	MISCELLANEOUS								
12	TOTAL SUPPLIES	13,500	13,900						
13	ENGINE ROOM REPAIRS								
14	BOILER " "								
15	PIPING REPAIRS								
16	TOTAL STEAM EQUIPMENT REPAIRS	2035	2200						
17	GENERATOR REPAIRS								
18	EXCITER SYSTEM REPAIRS								
19	INSTRUMENTS, SW BDS. ETC								
20	TOTAL ELECTRICAL REPAIRS	500	470						
21	PROPERTY REPAIRS	251	310						
	TOTAL COST	18,836	19,410						
	COST OF COAL PER TON	2.10	2.07						
22	TONS BURNED	3060	3278						
23	OUTPUT - IN 100 KW-HR.	35,500	37600						
24	POUNDS COAL PER KW-HR.	2.75	2.81						
25	TOTAL GENERATING COST PER KW-HR.	.530	.516						

COSTS PER KW-HR. - IN CENTS

6	TOTAL LABOR	.072	.0678						
12	" SUPPLIES	.380	.3700						
16	" STEAM REPAIRS	.037	.0585						
20	" ELECTRICAL REP	.014	.0125						
21	" PROPERTY REP.	.007	.0078						

FIG. 1. CLASSIFICATION AND COMPARISON OF ACCOUNTS

had 3500 boiler horsepower in his boiler room. He kept no records other than a few we might term "superficial" —measuring devices, other than steam gages, were entirely absent. Daily coal consumption could not be measured. Feed-water was taken from a 30,000-gal. tank. One day he conceived the idea of turning exhaust steam into this tank—under the circumstances, a good idea. The feed water increased in temperature, and from a chart he found that his coal consumption should decrease 10 per cent. He was elated, bragged of it, and expected a raise. After a time though, it was found the coal bills had not decreased—in fact, they had slightly increased —but why?

Well, the fact developed later, that through negligence the boilers had fallen into poor condition, seriously reducing their efficiency, more than offsetting the gain in feed water temperature.

This incident is mentioned merely to emphasize that had a system been in operation in that boiler room wherefrom the daily performance could be derived, or could even be approximated, several thousands of dollars might have been saved, actually, instead of only in the operator's imagination.

Curves for Comparison

The concrete, or tangible form for a cost analysis is graphic, that is, in curves. It costs more, and takes some time, but the simplicity it affords in comparison and deductions, repays many times. The purpose of this article is to show a typical analysis and some records—not as elaborate as the largest station might employ; at the same time probably quite beyond that applicable to the little plant—but the object is solely to convey an idea or a suggestion and not to design an analysis for

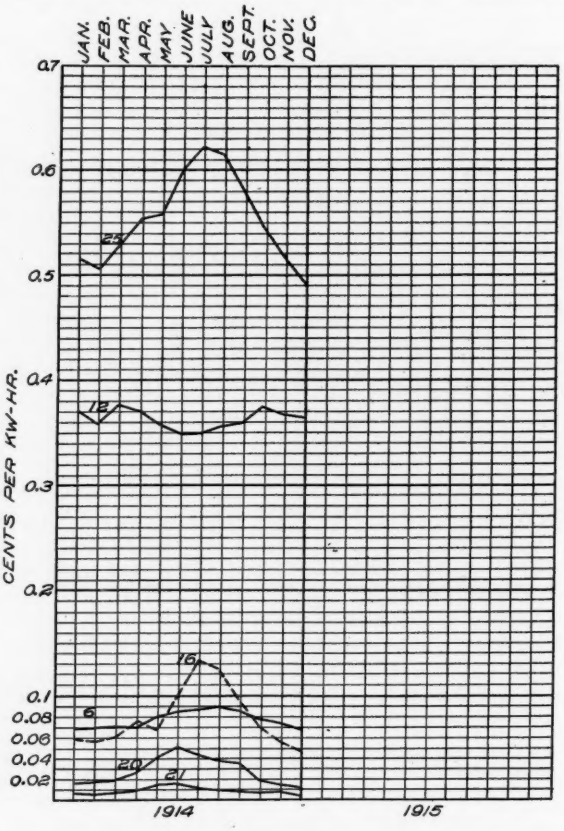

FIG. 2. COST CURVES USED FOR COMPARISON

any one individual plant. In other words, this is an endeavor to illustrate a cost-keeping method, believing its value and advantages will make themselves evident; to show some of the means devised to study costs, and their results.

We will assume a plant; consequently, each figure or quantity is an assumption. While endeavoring not to vary too far from accepted averages, exaggerations may be found; in some instances, perhaps, used for emphasis.

Cost of Plant Operation

For this purpose let us take a steam-electric plant, say, of 10,000 kw. capacity, consisting of 3 to 5 turbine or engine driven machines—modern in all details. Occasionally such a plant is found furnishing energy to an industry, or a group of industries, but is more typical

of a small city lighting plant. Assuming $55 per kw. installed, the apparatus is worth $550,000; allowing $20 for building and land, the latter investment is $200,000.

The number of headings or accounts in an analysis depends entirely upon the size of the plant—in small plants several or more items may be grouped in one; in larger plants, where these items are appreciable expense, they are given individual accounts.

Figure 1 presents a classification of accounts, which hardly seems too elaborate for even a small plant, for here many small items are grouped. In some larger plants, perhaps, each account of this chart is subdivided into several, and these again separated into material and labor accounts, affording a detailed analysis,

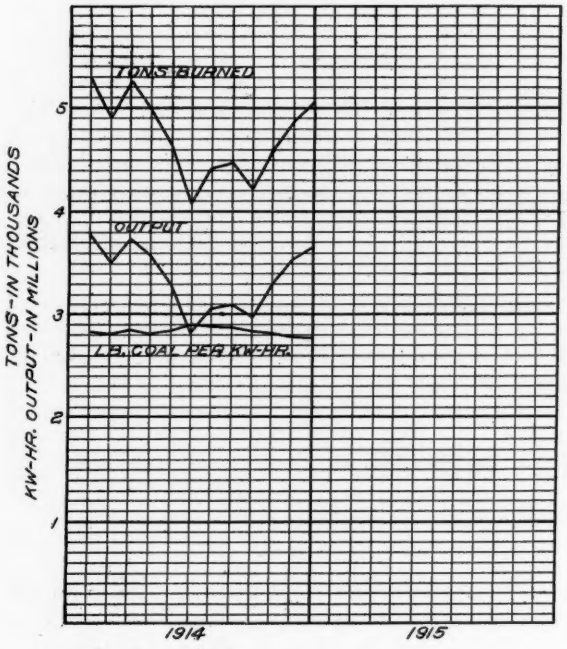

FIG. 3. CURVES OF OUTPUT AND COAL CONSUMPTION ARRANGED FOR COMPARISON

and this is further enhanced when each account is reduced to its cost per kilowatt-hour and described graphically. In any case, though, the graphic presentation of the total costs per kilowatt-hour and items 22, 23 and 24, should, if possible, be carried out, for the whole story is concentrated in these 9 accounts.

A Few Desirable Curves

It is advisable to plot the curves on charts of durable material, and of sufficient capacity to permit 5 or more years continuous record, month by month, thus affording a picture keenly interesting and of inestimable value. Figures 2 and 3 are given as an illustration.

One more chart, however, must not be overlooked and that is the percentage of the investment in machinery, and in land and buildings, required yearly to maintain each in thorough repair. This affords the only basis for comparison of different types of installation. In Fig. 4 it is assumed the plant has been in operation for several years. In the first year or two, at least, repairs should be small, giving a low percentage. The investment curve increases slightly, for in any plant, a certain amount of new apparatus is always being installed.

Consideration of Fuel

Coal, or fuel, is the big item of expense. In our assumed plant a little increase in the pounds per kilowatt-hour means a large increase in dollars. This increase can occur from only 2 causes—poorer coal, or poorer handling. The first must be stopped, if possible; the second must be remedied; consequently it is up to our engineer to know the daily performance. He will devise a record, the essence of which is as follows:

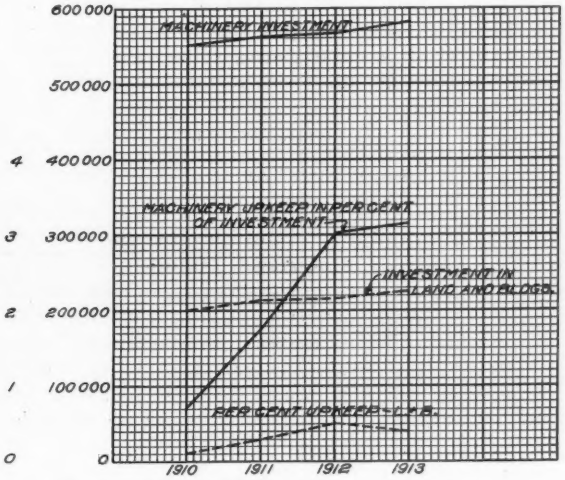

FIG. 4. INVESTMENT AND UPKEEP CURVES

May 10, 1912.

Coal in bunkers, May 10, 7 a.m.....
Coal unloaded, May 10.....
Coal in bunkers, May 11, 7 a.m.....
Coal consumed, May 10.....
Kw. output, May 10.....
Lb. coal per kw.-hr.....

The coal unloaded, has previously been weighed. The estimate of the coal in the bunkers is made by an employe, but while this may seem rather crude, it is surprising how accurate an intelligent man will become. In one known instance, such a man's estimates do not vary more than 3 per cent from the correct monthly figures, so that any serious fluctuation in coal consumption is quickly noticed. Next, what shall be the basis for buying fuel? Buying B.t.u. appears logical, but often undesirable physical conditions in coal offset a high B.t.u. value and the purchaser is disappointed. Why not buy it basing the purchase on its actual evaporating ability? In any locality, coal usually is supplied from the most convenient coal field. This means that the greater part of the supply is composed of a few definite grades. Therefore, in a plant of this size, it would be advisable to rig up one boiler for testing purposes, at various times trying out the different coals on the basis of the cost to evaporate a certain amount of water from and at 212 deg. F. Such tests should last not less than 4 hr. and by weighing the feed water to this boiler, service is not interrupted.

In the Boiler Room

Destruction takes place rapidly in the boiler room. It is not amiss to say that the true value of any material to any plant depends entirely on its results when working under that plant's conditions. Therefore, no new material should come into a plant without the engineer obtaining for himself its value to him. If new fire brick is used, new arches, settings, valves, or other items are installed, he will find it to his interest to keep an accurate record of all costs of renewal and maintenance over a period of time sufficiently long to afford reliable data.

In their search for cost analysis a plant of boasted economy maintains a cost account of maintenance for each class of apparatus in its boiler room, each type of valve, the various parts of furnaces, etc., are included. This is expensive, but the closeness with which it defines costs often results in producing valuable economies by pointing out otherwise overlooked "high spots."

Engine Room Apparatus

Coming to the engine room the neglected condenser offers the greatest leak. Slight decreases in the high vacuum, so essential to turbines, mean increased coal consumption, consequently condenser vigilance should never cease. Always observe condenser pressures with a mercury gage. Maintain every joint absolutely tight. A certain plant, by constant effort, maintains an average back pressure of 1¼ in. which formerly had difficulty in keeping 2½ in. This was in part accomplished by eliminating the carelessness of machine operators. A record of instantaneous load and vacuum readings was devised, and taken at unexpected times during the day, independent of the machine's log. This caught the low-reading machines, at the same time putting the operator on the defensive.

Lubricants present, often, a source of waste by injudicious feed. The oil per engine hour invariably is reduced when a record of engine hours and oil used on the various engines affords comparison. Having the comparison, it only remains to ascertain whether the engine or the attendant is at fault.

Lastly, the service ability or reliability of a plant's apparatus may be put in tangible form by numerically listing all sources of trouble against the different apparatus, and classifying according to its seriousness. For example, some troubles might necessitate shutting down a plant, might require taking a piece of apparatus out of service, or be of lesser importance. This monthly summary of troubles charged against boilers, engines, auxiliaries, etc., is not only interesting, but advantageous in that it arrests attention on the apparatus which is the most frequent violator, thus offering a step in the direction of producing or requiring material of greatest reliability.

Remember that every time you save a pound of coal, you are aiding in the great work of the conservation of our natural resources, as well as developing yourself to be of greater usefulness.

Comparison of Results

Most Desirable System of Records, How it May be Developed and Improved, Methods of Comparison. By Stonewall Tompkins*

Comparative study of results offers a fruitful and generally the best means for detecting and preventing waste and for improving the all around efficiency of a plant. This is particularly true if the work be carried on with system and regularity and the comparisons are extended to other plants as well as to various periods and conditions of the same plant in which the results are obtained.

Few, if any, successful power plant managers doubt the truth of all this, yet small still is the number who cannot learn something new about it from almost any one else of experience in this line. Therefore, no prolonged argument seems needed on the importance of the comparison of power plant records. Since, however, it is necessary to *have* the records before they can be compared and it is highly desirable to have them in a convenient form, it will be well to give some time to a discussion of the subject of making and preserving records for future comparison.

In any undertaking it is well to have high ideals, and although a perfect ideal can never be fully realized—and it is generally unwise to strive to accomplish the impossible—it is well to have a perfect ideal or at least the highest conceivable one which, although unattainable, can often be useful in analyzing the conditions and finding the limits beyond which it will be unwise to pass in working toward the perfect ideal. This method will generally result in formulating a high, though entirely practical, standard for use in gaging actual results.

Following this line of thought an effort will be made to define the highest conceivable ideal in the line of power plant records and to discuss methods for arriving at practical results of high order.

The Perfect System

The first suggested definition of a perfect system of power plant records is as follows:

A system of records which for the lowest attainable cost will supply all needed information on previous operation.

This definition includes on the one hand "all needed information" and on the other hand excludes everything else because there would be some additional cost involved in recording and preserving additional information, as well as in searching through it to find the needed data. The term "needed information" is here intended to signify information which will be needed at some time in the future. One foremost reason why this system is impossible is that it requires foreknowledge of

*Completing the engineering course at the University of Virginia, Mr. Tompkins taught engineering for 8 yr. in the Miller School and for 4 yr. thereafter was Professor of Mechanical Engineering and Director of the Engineering Department of South Carolina Mechanical College. During this time he selected and installed the equipment of shops, laboratories and power plants for these 3 institutions, and did similar work for the Universities of Tennessee and Arkansas, besides supervising construction of other steam and water-driven power plants. For 8 yr. he has been in engineering practice on rice irrigation plants, cotton machinery, as general manager of light and power company and 4 yr. Chief Engineer of the Coney Island and Brooklyn R. R., in charge of all plants, rolling stock, and operation.

what information will be needed. The necessity for this foreknowledge would be removed if it were possible to make records contain full data on *every* occurrence connected with the plant, because such records could supply any and all needed information. However, this would not measure up to the above definition, because much of the data would never be needed and the useless cost involved in securing, recording and filing the needless data as well as in rummaging through such voluminous records for needed information, would be very great.

The impossibilities of such a system render its further discussion undesirable for the present purpose and there-

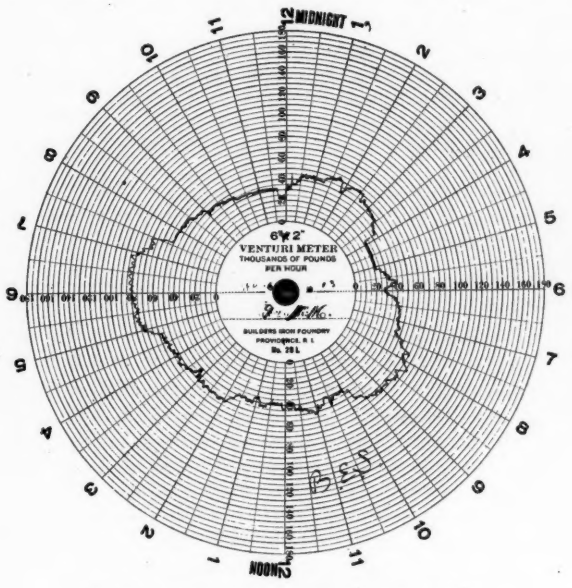

FIG. 1. RECORD FROM FEED-WATER METER

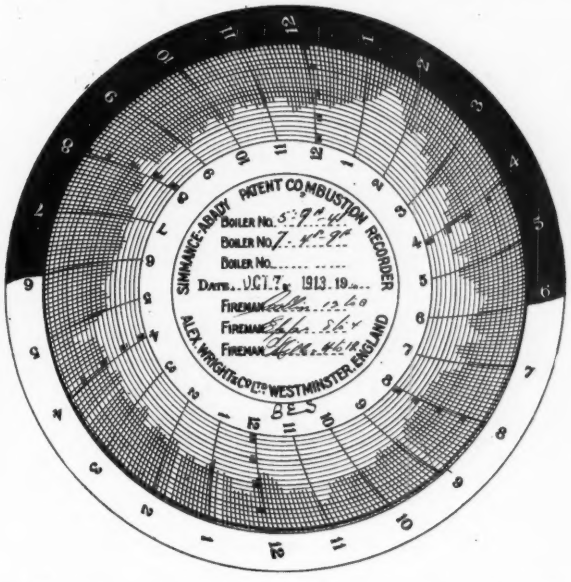

FIG. 2. RECORD OF COMBUSTION GIVING CO_2 IN PER CENT

Form L-703

CONEY ISLAND AND BROOKLYN RAILROAD

SMITH STREET POWER HOUSE
BOILER ROOM LOG SHEET

FOR 24 HOURS ENDING MIDNIGHT October 31 , 1913

DURATION OF TIME IN SERVICE

	12	1	2	3	4	5	6	7	8	9	10	11	Noon	1	2	3	4	5	6	7	8	9	10	11	12
Boiler No. 1																									
" " 2	/	/	B*	B	B	B	/	/	/	/	/	/	cut in	/	/	/	/	/	/	/	B	B	B	B	
" " 3									started fire					/	/	/	/	/	/	/	/	/	/	/	
" " 4	B	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	
" " 5	B	B	B	B	B	B	B	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	
" " 6																									
" " 7	/	B	/	/	/	/	/	/	/	/	/	/	cut out												
" " 8																									
" " 9																									
" " 10																									
" " 11																									
" " 12																									
Feed Pump " 1																									
" " " 2																									
Blower " 1																									
" " 2																									
" " 3																									
" " 4																									
Feed Water Temp. F	196	197	199	201	205	199	192	186	180	182	185	185	181	185	188	190	182	179	175	177	184	189	195	198	
Tons Coal Used — Recorded elsewhere																									
Water Tenders	← H Collins →								← Chas Epps →								← Jno Smith →								

REMARKS: Mention any breakdown or unusual occurrence; also all boilers, pumps, or other apparatus laid up for repairs, etc.

#7 Boiler cut out for inspection

*1. indicates in service
*B. indicates banked but not generating any appreciable steam

C.A.W.

FIG. 3. LOG SHEET FOR BOILER ROOM PROVIDING FOR HOURLY READINGS

fore an approximately ideal system will now be considered.

A desirable system practically better than the preceding one would be:

A system which would contain no useless data and only such needed information as future conditions would make of sufficient value to justify the cost of its preparation and preservation.

The essential difference between these 2 definitions is that the latter one dispenses with some of the useful information which the first would provide, the portion rejected being that which is not sufficiently useful to justify its cost.

Probably no one will read this article who would not admit that any power plant could lose financially by too little record keeping, and it is certain that record keeping could be multiplied to such an extent that there would be a financial saving in dispensing with part of it. In such an ideal system the point to be aimed for is not easily discernible and is, therefore, difficult to reach, but is not absolutely impossible of attainment, though it might be reached or passed without such fact becoming known.

To illustrate this matter, let it be assumed that a given plant at first keeps no records and suffers financial loss in consequence. The next step would be for it to begin to keep a few records and only such as would be the most productive of financial economy. Thereafter there should be gradual additions to the record keeping, each addition being the one which would yield the next best financial return. This process could go on step by step until a point would finally be reached where any further addition to the system of record keeping would be financially unprofitable.

If such a process be approximately possible—and seemingly this must be admitted—it is possible by gradually developing a system to arrive at and pass beyond the limit of profitable record keeping.

Such an approximately ideal system of records as this cannot be fully carried out in practice, but it approaches nearly enough to the bounds of possibility to serve as a useful standard if handled with a fair amount of that

CONEY ISLAND & BROOKLYN RAILROAD

SMITH STREET POWER HOUSE

ENGINEER'S DAILY LOG FOR 24 HOURS ENDING MIDNIGHT October 31 - 1913

DURATION OF TIME IN SERVICE — A M 12 1 2 3 4 5 6 7 8 9 10 11 Noon 1 2 3 4 5 6 7 8 9 10 11 12 P M

A. C. Gen. No. 1 … No. 6; D. C. Gen. No. 1 … No. 7; Exciter No. 1, No. 2; DeKalb Av. Cable, No. 4; Kings High'y No. 1 … No. 3; Smith St No. 5, No 6; Step Bearing Pump, No. 1, No. 2; Other No. 1, No. 2; Dry Vacuum No. 1, No. 2; Centrifugal No. 1, No. 2

These generators have been sold

ENGINEER: Chas E Rochelle | W H Mc Queen | Geo R Warner

WATT METER READINGS

Meters to be read at 12 o'clock each night		Kilowatt Hours
A. C. Gen. No. 1	Present Reading / Previous Reading / Difference K.	Generators not equipped with meters - see cable meters
A. C. Gen. No. 2	Present Reading / Previous Reading / Difference K.	
	Total A. C. Steam	22890
D. C., Total	Present Reading / Previous Reading / Difference K.	
	Total D. C. Steam	
	Total Steam	43580
Cable No. 1	Present Reading 18°-0 / Previous Reading 16880 / Difference K.	260
Cable No. 2	Present Reading 132230 / Previous Reading 112210 / Difference K.	10020
Cable No. 3	Present Reading 455260 / Previous Reading 453200 / Difference K.	2060
Cable No. 4	Present Reading 919110 / Previous Reading 909120 / Difference K.	9990
Rotary No. 5	Present Reading 102010 / Previous Reading 765210 / Difference K.	16670
Rotary No. 6	Present Reading 971580 / Previous Reading 970000 / Difference K.	1580

			K. W.
Max. 15 Min. Peak A. C. Steam		4325	
" " " D. C. "		none	
" " " Total "		4325	
Max. One Hour Ave., Total Steam		4050	
Per Cent. Load Factor, Total Steam			
Lbs. Coal Consumed for Power		152,670	
Consumed for other Purposes		none	
Total Coal Consumed		152,670	
Lbs. Coal Consumed per Kilowatt Hour		3.505	

WATER METER READINGS

Smith Street No. 1	Present Reading / Previous Reading / Difference		Cu. Ft.
Ninth Street No. 2	Present Reading	71800	
	Previous Reading	71300	
	Difference		500 Cu. Ft.
Ninth Street No. 3	Present Reading	1150 5430	
	Previous Reading	1148 9620	
	Difference		15810 Cu. Ft.
	Total Water Used		16310 Cu. Ft.

Temp. Feed Water °F.	Max		Min.	
Steam Pressure	"	185	"	169
Vacuum	"	29	"	28
	8.00 A. M		6.00 P. M.	
State of Weather		Clear		Clear
Temperature of °F.		46°		46°
A. C. Engine Hours		26		
D. C. " "				
Total		26		
Temp. Steam at Turbine	6.00 A. M		6.00 P. M.	

not yet equipped to record

Water high on account of filling Boiler #3

REMARKS (Mention apparatus disabled with causes and unusual occurrences of any sort).

12 Mid #2 Gen #1 Exciter #1 Roty
#1-2-3-4-5 Feeders in service A C
Bus tied Bus switches closed on
#2 Gen #1-2-3-4-5-6 Feeders -
Open on #1 Gen
6.30 A M Highway & L reported ready
9.30 " cut in #2 cut #1 Exciter
4.45 P M Cut in #1 Exciter
4.50 " Closed Bus switches #1 Gen
5.00 " Cut in #1 Gen
5.00 " Cut in #2 Roty
7.00 " Cut out #2 Roty
7.00 " Cut out #2 Gen
7.05 " Opened Bus switches #2 Gen
7.15 " Cut out #1 Exciter
10.00 " Hvgl 10, N & L reported Offline

Hard coal 127180
Soft coal 25490
152,670

Percent soft coal 16
Water per K W H 26.607
Wat. lb coal 7443
Passes issued 64

C A M.

FIG. 4. LOG SHEET OF ENGINE ROOM

uncommon commodity called "common sense" which is an important factor in success of any kind.

A broad view of the matter is necessary and something akin to prophetic judgment is desirable because the object of records is to supply information which will be needed in the future. But since the past and the present are the only sources of information on the future, it would seem that the most correct judge of the past and present should be the best prophet for the future.

If all plants in the same line of work could be brought to using the same standard forms of records, a great improvement would result. A large number of power plants are now being supervised by public commissions and these commissions often demand voluminous reports which throw unnecessary expense upon the plants; nevertheless benefits of importance often come from keeping the records required by the commissions, and far greater benefits would result if the various com-

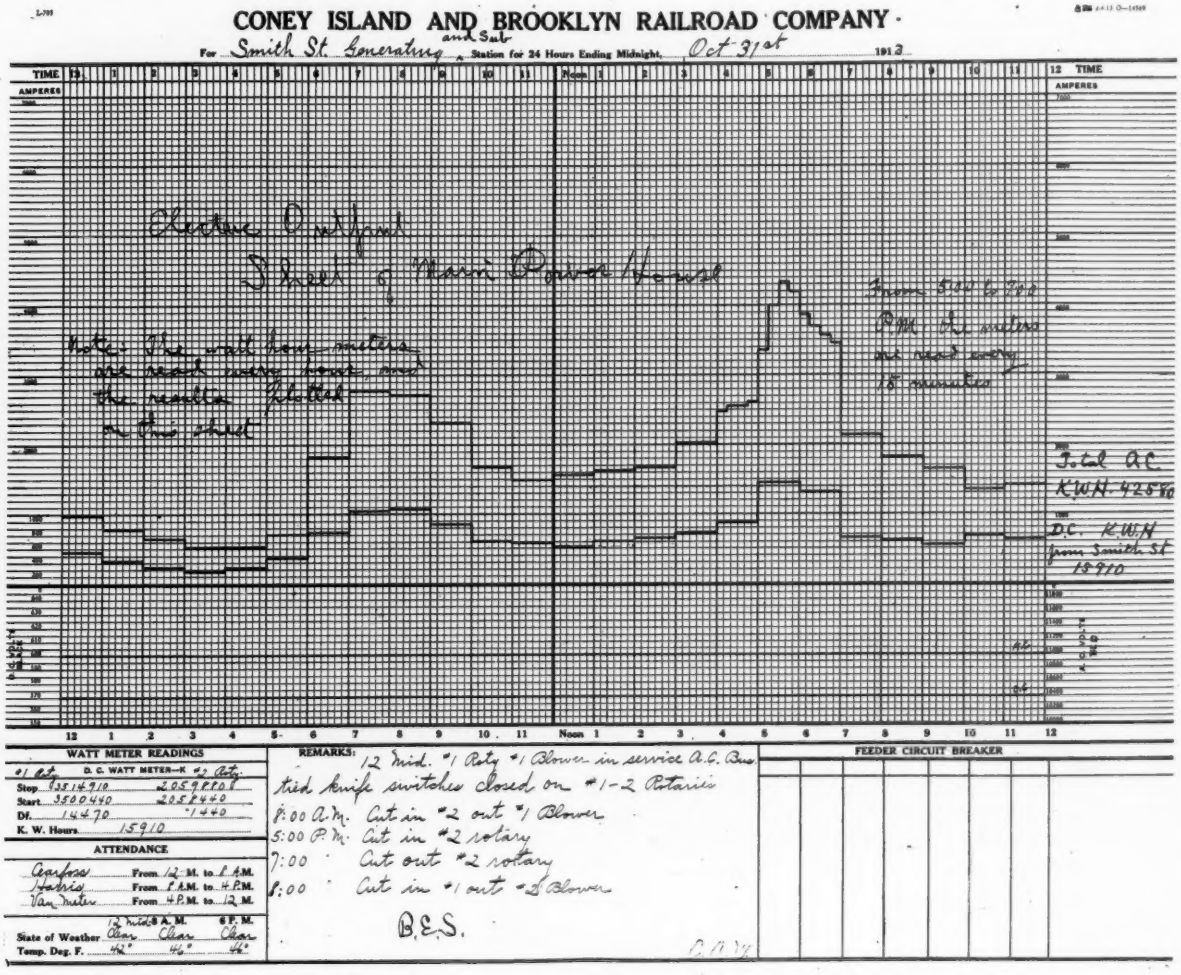
CONEY ISLAND AND BROOKLYN RAILROAD COMPANY
For Smith St. Generating and Sub Station for 24 Hours Ending Midnight, Oct 31st 1913
TIME
AMPERES
Electric Output
Sheet of Main Power House
Note: The watt hour meters are read every hour, and the results plotted on this sheet
From 5:00 to 7:00 P.M. the watts are read every 15 minutes
Total AC KWH 42580
DC. KWH from Smith St. 18910
WATT METER READINGS
#1 Rty
D. C. WATT METER—K #2 Rty
Stop 3351490 2059220
Start 3500440 2052440
Df. 14470 7440
K. W. Hours 15910
ATTENDANCE
Agnew From 12 M. to 8 A.M.
Harris From 8 A.M. to 4 P.M.
Van Nuter From 4 P.M. to 12 M.
State of Weather 12 mid. Clear 8 A.M. Clear 6 P.M. Clear
Temp. Deg. F. 44° 46° 46°
REMARKS: 12 Mid. #1 Roty #1 Blower in service A.C. Bus tied knife switches closed on #1-2 Rotaries
8:00 A.M. Cut in #2 out #1 Blower
5:00 P.M. Cut in #2 rotary
7:00 " Cut out #2 rotary
8:00 " Cut in #1 out #2 Blower
B.E.S.
FEEDER CIRCUIT BREAKER

FIG. 5. ELECTRIC OUTPUT SHEET OF MAIN POWER HOUSE

Improving Present Systems

There is probably no power plant of consequence which does not keep some records, hence it is more important to discuss ways for improving established systems than for starting new ones. In applying the preceding ideas 2 things should be ever in mind; the first is to increase the value of the records, and the second is to decrease the cost of making, keeping and using them. An improvement in either of these directions would justify the extension of a system which had previously reached its economic limit. The chief value of records comes from comparative study of them and whatever will further increase or facilitate comparison will increase their value. Nothing else is more important along this line than conformity to proper standards.

missions throughout the country would adopt uniform standards in the reports they require of plants and strive to make these reports measure as nearly as possible up to the standard of omitting no valuable data and containing none which could profitably be omitted.

The commissions are apt to ask for more data than many plants are well prepared to supply, therefore, it is well for a plant to adopt forms for the tabulation of records which will accord as nearly as may be with the information called for by the commissions and not add thereto unless it would seem profitable to do so. If the work of the commissions results in uniformity of records of plants without useless expense, much good will result.

Other valuable features of records are accuracy, clearness and the greatest brevity consistent with giving the desired information. A convenient system of filing is also desirable, because the usefulness of records depends largely upon being readily accessible when needed.

All that has been said applies to the original records and also to tabular or graphic comparisons prepared from the originals, but some of the following remarks apply more particularly to the original records.

The value of a record may be much impaired by the omission of a date, a signature, a note on the weather or something of this kind. The original records should be promptly and regularly examined by some one with a view to supplying deficiencies, which can generally be done if the examination is not long delayed. The examiner should always write his name or initials on the report to indicate that he has seen it and considers it correct and complete.

It is becoming more and more the practice to use autographic recording instruments in making original records. There are some excellent recording instruments, some that have a questionable value and quite a number that undoubtedly are bad investments. It is hoped that the number of such devices which it pays to use will steadily increase, because no other record is quite so good as an autographic one which is correct and clear.

The records which are here illustrated to bring out some of the above points are those of a steam driven electric railway plant of medium size which perhaps comes as near to being representative of all plants as any one plant can well be. It contains 2 3500-kw. steam turbine driven alternators and 1 800-kw. reciprocating direct-current unit, and there are 3 substations.

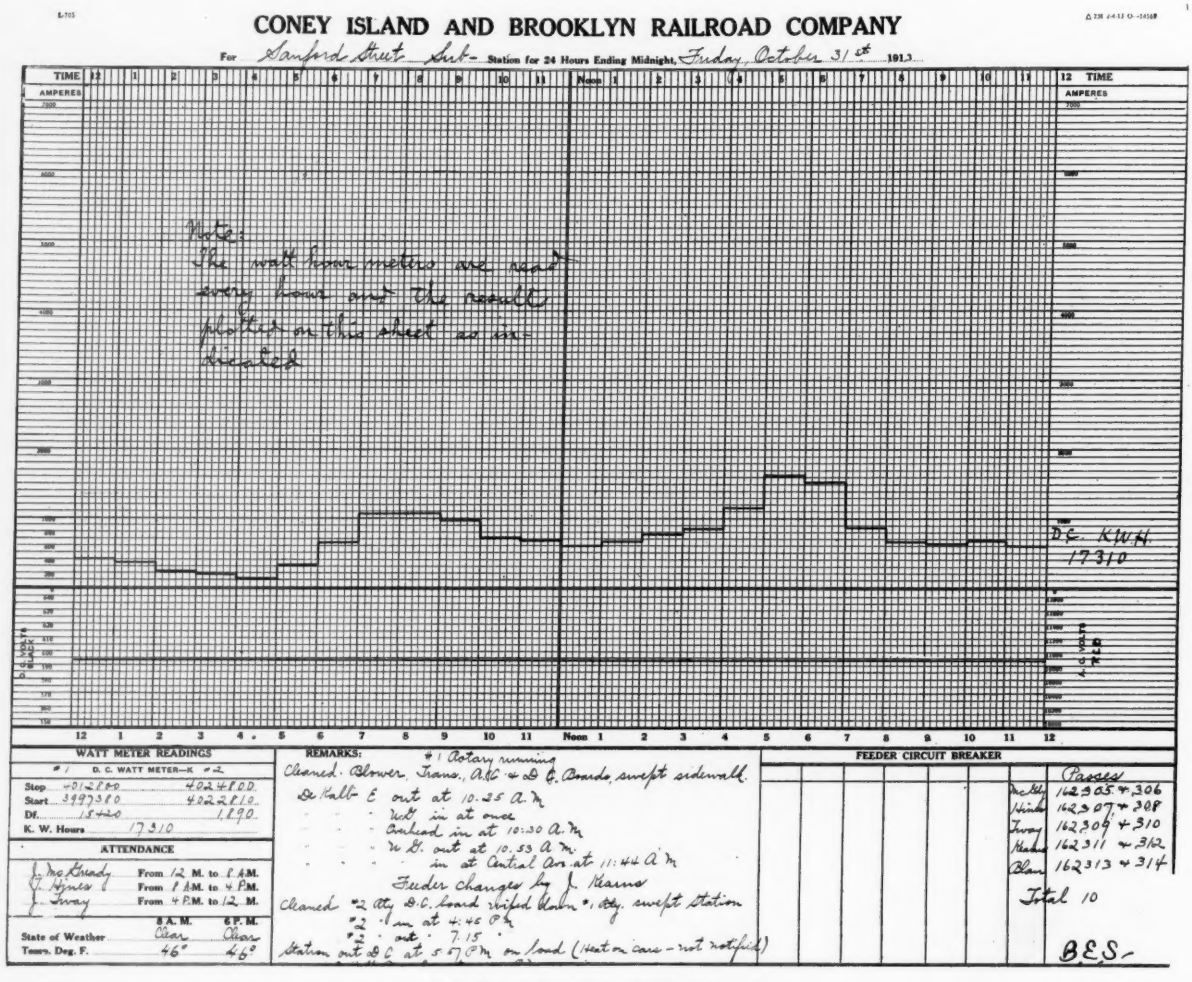
CONEY ISLAND AND BROOKLYN RAILROAD COMPANY
For Sanford Street Sub-Station for 24 Hours Ending Midnight, Friday, October 31st 1913
TIME
AMPERES
12 TIME
Note:
The watt hour meters are read every hour and the results plotted on this sheet as indicated.
D.C. KW.H.
17310
WATT METER READINGS
D. C. WATT METER—K =2
Stop 4012800 4024800
Start 3997380 4022810
Dif. 15420 1990
K. W. Hours 17310
ATTENDANCE
Mc Grady From 12 M. to 8 A.M.
Hynes From 8 A.M. to 4 P.M.
Irving From 4 P.M. to 12 M.
8 A.M. 6 P.M.
State of Weather Clear Clear
Temp. Deg. F. 46° 46°
REMARKS:
#1 Rotary running
Cleaned Blower, Trans., A.C. & D.C. Boards, swept sidewall.
D.C. Volt E out at 10.25 A.M.
" " Volt in at once
" " Ambead in at 10:30 A.M.
" " W.E. out at 10.53 A.M.
" " in at Central Ave at 11:44 A.M.
Feeder changes by J. Harris
Cleaned #2 Aty D.C. board Rifled Motor #1 Aty. swept station
#2 " on at 4:45 P.M.
#2 " out " 7.15 "
Station out D.C. at 5.57 P.M. on load (Heat on cars - not notified)
FEEDER CIRCUIT BREAKER
Passes
McKay 162305 + 306
Hinds 162307 + 308
Irving 162309 + 310
Hanbe 162311 + 312
Olsen 162313 + 314
Total 10
B.E.S.

FIG. 6. SUBSTATION REPORT SHEET

The original records from this plant which are shown are: An autographic water meter record of the feed-water to the boilers, an autographic combustion record, a boiler room log sheet, an engineer's log sheet, an electric output sheet from the main power house and a sheet from one of the substations.

These forms have been developed gradually somewhat as indicated in the foregoing assumed case and it is now rare for any data on previous operation to be needed which cannot be gotten from them.

All these reports are sent to the chief engineer's office daily where they are examined and filed away. Once a month a tabular statement of power plant economy is made, which statement has a column for the results of the particular month and for the corresponding month of the previous year. There are also columns giving the results for the entire period from the beginning of the fiscal year up to the end of the particular month, together with the results of the like period of the previous year. This makes comparison very convenient, but added facility is caused by recording these differences and the percentages of same in parallel columns, while

POWER PLANT ECONOMY

	FOR THE MONTH OF SEPTEMBER				FOR THE THREE MONTHS FROM JULY 1ST - 1913			
	1913.	1912.	Increase or Decrease	Per Cent.	This Fiscal Year to Date	Last Fiscal Year to Date	Increase or Decrease	Per Cent.
CURRENT GENERATED								
A.C current—kwhrs. Smith St.	1,223,480	1,215,350	8,130	.67	4,180,820	4,103,490	77,330	1.75
D.C. current—kwhrs. Smith St.						57,144	-57,144	
TOTAL KWHRS. GENERATED	1,223,480	1,215,350	8,130	.67	4,180,820	4,160,634	20,186	.49
CURRENT DISTRIBUTION								
Smith St. generating station—D.C.						57,144	-57,144	
Smith St. sub-station—D.C.	406,630	420,000	-13,370	-3.18	1,315,690	1,307,260	8,430	6.45
DeKalb sub-station—D.C.	476,690	411,900	64,790	15.73	1,533,150	1,329,100	204,050	15.35
Kings Highway sub-station—D.C.	174,610	175,975	-1,365	-.78	768,330	736,400	31,930	4.34
TOTAL APPLIED TO STREET RAILWAY	1,057,930	1,007,875	50,055	5.01	3,617,170	3,429,904	187,266	5.46
D.C used for other purposes	8,940	11,880	-2,940	-24.75	38,840	53,700	-14,860	-27.67
TOTAL D.C.	1,066,870	1,019,755	47,115	4.62	3,656,010	3,483,604	172,406	4.95
A.C used for other purposes								
Lost or unaccounted for	156,610	195,595	-38,985	-19.94	524,810	677,030	-152,220	-22.48
TOTAL	1,223,480	1,215,350	8,130	.67	4,180,820	4,160,634	20,186	4.85
COST OF OPERATION								
Power plant labor	2,212.48	2,164.36	48.12	2.22	6,772.81	6,559.73	213.08	3.20
Fuel for power	4,770.44	4,646.02	124.42	2.68	15,475.77	14,771.12	704.65	4.77
Water for power	525.97	953.53	-427.56	-44.84	1,781.16	1,473.33	307.83	20.89
Lubricants for power	11.95	4.20	7.75		73.15	108.47	-35.32	-32.56
Other supplies and expenses	556.79	4,959.44	-4,402.65	-88.76	1,539.55	7,567.08	-6,027.53	-79.66
TOTAL GENERATING POWER PLANT	8,077.63	12,727.55	-4,649.92	-36.54	25,642.44	30,479.73	-4,837.29	-15.87
Sub-station labor	521.68	555.81	-34.13	-6.14	1,530.19	1,717.71	-187.52	-10.92
Sub-station supplies and expenses	7.33	3.92	3.41	87.00	55.70	50.44	5.26	10.43
" " maintenance	33.50	.25	33.25		47.63	99.59	38.04	
TOTAL OPERATION OF POWER PLANT	8,640.14	13,287.53	-4,647.39	-34.97	27,275.96	32,257.47	-4,981.51	-15.45
Cost of all exchanged power balance	2,044.55	1,975.41	69.14	3.50	10,994.70	7,903.13	3,091.57	39.12
TOTAL COST OF POWER	10,684.69	15,262.94	-4,578.25	-30.00	38,270.66	40,160.60	-1,889.94	-4.71
COAL								
Bunker bit used (100 lbs.)	7,249.00	4,616.13	2,632.87	57.04	21,352.10	15,941.73	5,410.37	33.94
Bunker anth used (100 lbs.)	39,142.20	22,016.02	17,126.	77.80	128,920.10	85,812.12	43,107.98	50.24
Stored anth. used (100 lbs.)		12,122.86	-12,123.		2,258.50	28,474.88	-26,216.38	-92.06
TOTAL (100 LBS.)	46,391.20	38,755.03	7,636.17	19.71	152,530.70	130,228.73	22,301.97	17.13
Per cent. bit. coal used	15.63	11.91	3.72	31.23	14.00	12.24	1.76	14.38
Cost bunker bit. used	970.85	633.38	337.47	53.29	2,846.24	2,150.14	696.10	32.37
Cost bunker anth. used	3,477.37	1,955.20	1,522.17	77.86	11,453.17	7,622.83	3,830.34	50.26
Cost stored anth. used		1,488.25	-1,488.25		277.27	3,495.75	-3,218.48	-92.07
TOTAL	4,448.22	4,076.83	371.39	8.60	14,576.68	13,268.72	1,307.96	9.85
Cost per cent. bit. used	21.83	15.54	6.29	40.48	19.53	16.21	3.32	20.48
ECONOMY								
Pounds coal per kwhr gen.	3.791	3.188	.603		3.645	3.130	.515	
Water per kwhr gen.	27.352	22.397	4.955		26.792	22.444	4.348	
Water per pound of coal	7.213	7.023	.190		7.341	7.170	.171	
Loss up to sub-station D.C. bus.	12.68	16.09	-3.41		12.55	16.25	-3.70	
Cost								
Labor per 1000 kwhr. gen	1.808	1.781	.027		1.620	1.577	.043	
Fuel per kwhr. gen.	3.899	3.823	.076		3.702	3.550	.152	
Water per kwhr. gen.	.430	.785	-.355		.426	.354	.072	
Lubricants per kwhr. gen.	.028		.028		.018	.026	-.008	
Other supplies & exp. per kwhr. gen.	.455	4.081	-3.626		.368	1.819	-1.451	
Total per kwhr. gen	6.620	10.470	-3.850		6.134	7.326	-1.192	
Per kwhr. D.C.	8.099	7.675	.424		7.461	8.745	-1.284	
Per car mile ¢	1.891	2.325	-.434		1.649	1.564	.085	
POWER CONSUMED BY CARS								
C I & B car miles operated	523,915	545,112	-21,197	-3.89	1,874,480	1,940,801	-66,321	-3.42
Deduct car miles on B. R. T. power	97,585	100,246	-2,661	-2.65	313,483	323,865	-10,382	-3.21
Add B R.T. car miles on C.I. & B. power	20,349	19,477	872	4.48	62,430	61,561	869	1.41
Total B.R.T and C.I.&B car miles	446,679	464,343	-17,664	-3.80	1,623,427	1,678,497	-55,070	-3.28
Other foreign car miles on C.I.&B. power	10,181		10,181		31,696		31,696	
Net car miles on C I.&B. power	456,860	464,343	-7,483	-1.61	1,655,123	1,678,497	-23,374	-1.39
Power consumed by other foreign cars	30,543		30,543		96,088		96,088	
Kwhr per car mile B R.T.&C.I.&B. cars	2.300	2.170	.130	5.99	2.170	2.043	.127	6.22
Net kwhr per car mile.	2.315	2.170	.145	6.68	2.185	2.043	.142	6.95
HIRED POWER—BRIDGES								
Car miles on B R T power	68,549	71,712	-3,163	-4.41	221,898	231,700	-9,802	-4.23
Kwhr per car mile	2.279	2.458	-.179	-7.28	2.279	2.458	-.179	-7.28
Cost of B. R. T. power	2,056.47	2,151.37	-94.90	-4.41	6,656.95	7,303.94	-646.99	-8.86
Cost per car mile B. R. T power ¢	3.000	3.000			3.000	3.000		
Cost per kwhr B R. T power ¢	1.349	1.401	-.052	-3.71	1.349	1.401	-.052	-3.71

all these items are for 1000 kwhr.

FIG. 7. MONTHLY REPORT OF POWER PLANT ECONOMY

the eye is still further attracted to the differences by using red ink wherever the figures for the current year are lower than for the preceding one. In the cut this distinction is noted by the minus sign.

A hasty glance over this monthly sheet of power plant economy will convey to any person familiar with such work an accurate idea of the operation of the plant as compared with the like period of the preceding year. The collection of data into this tabular form and copying it in 2 colors on a duplicator is an inexpensive operation and provides ample copies for all properly interested persons, and extra sheets to be used in the exchange of data with other plants, thus greatly increasing the facilities for such comparison as is most effective in the improvement of efficiency. A sample monthly sheet is illustrated herewith.

Graphic comparisons of records are generally more striking to the eye than tables can well be and their use is often desirable. A graphic comparison of some of the records of the plant in question is shown herewith which covers a complete period of 2 calendar years and quickly gives the comparison of any one month with another, but more especially of 2 corresponding months of the 2 years.

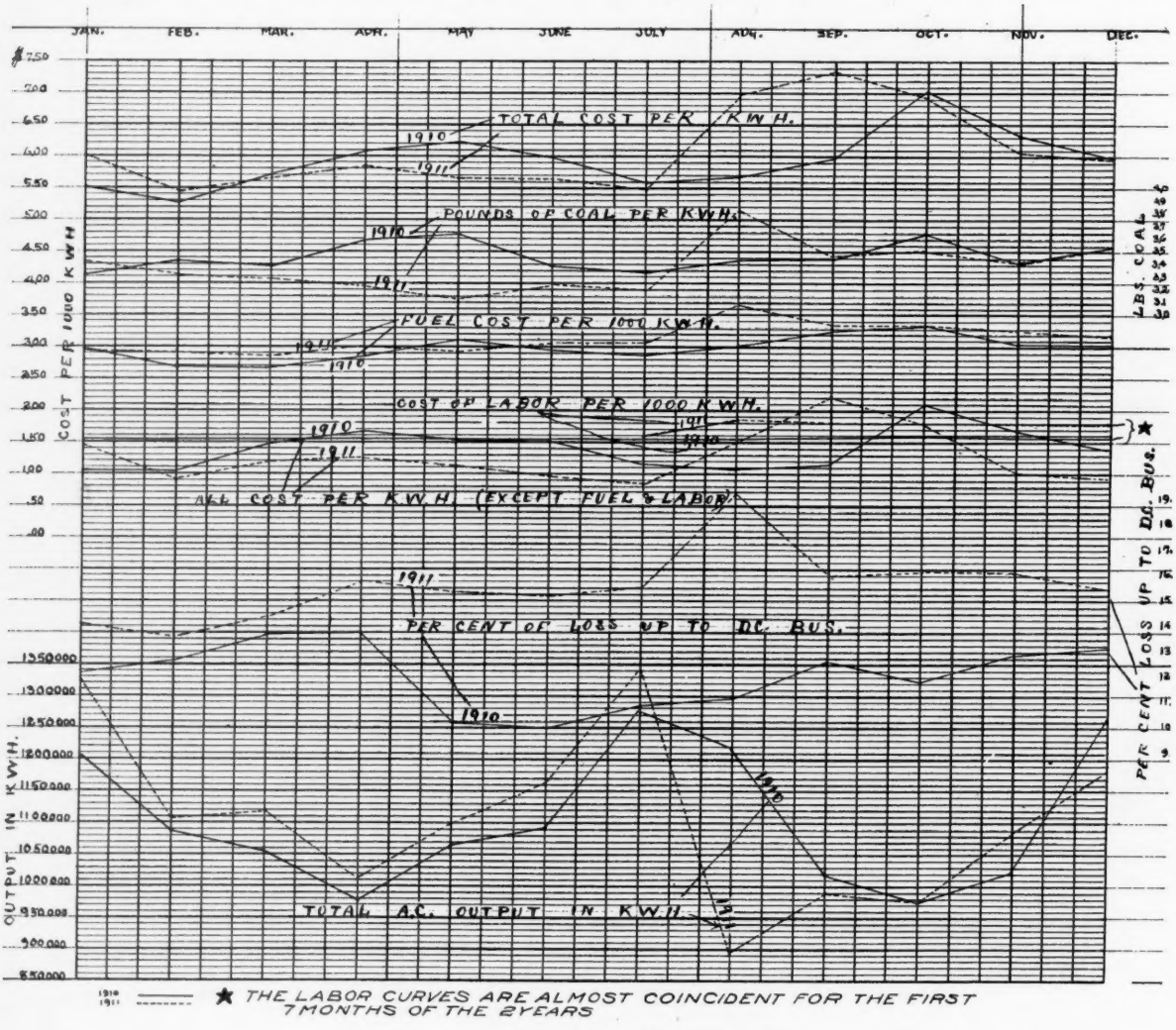

FIG. 8. GRAPHIC COMPARISON OF RECORDS

The Wamesit Power Co. of Lowell, Mass., was granted a permit recently from the office of the superintendent of lands and buildings for the erection of a brick addition to its present power house, which will cost $1800. The new building will adjoin the north end of the present building, and, as its necessity is urgent, will be rapidly constructed.

Sulphur Springs (Tex.) Electric Light and Power Co.'s new brick building is under construction and will be completed in the near future. The owners, Ashcroft & Sons, expect to spend about $20,000 in betterments as soon as the new building is finished. The most modern electrical machinery will supplant the present system.

Pain is no evil unless it conquers us.—George Eliot.

Power Costs

AVERAGE RESULTS OBTAINABLE IN THE BEST PLANTS OF VARIOUS SIZES BURNING COAL AND OIL. BY REGINALD TRAUTSCHOLD*

AS practically every undertaking requires power of some description, efficient operation is possible only when power is obtained at a minimum cost. Economy in the production of power is, in fact, the basis of operating efficiency. Installation of improved machinery, a cutting down of an expense here or a saving there cannot wipe out an undue burden imposed by expensive power. The remedy lies in the power house—usually a steam plant—and the multiplicity of conditions affecting its efficient operation is such that no individual plant can arrive at the best results entirely through experiment with or testing out of its own equipment. Comparison with the results and practice of other plants is necessary and a basis for such comparison is best established by a tabulation of the results of power plants of acknowledged economical operation.

Investigation into the cost of producing power in a large number of efficiently operated power houses shows that, except for the item of fuel, there is comparatively little variation in expense between plants of similar size. With fuel at a fixed price, there is an "efficiency record" that should be equalled by any economical power house of specific capacity—a record that is bettered only by a comparatively few plants that operate under exceptionally advantageous conditions—and which may then be taken as a basis for efficiency. This is true, notwithstanding the fact that a certain variation in initial cost of plants of given size does exist, due to varying land values, cost of construction, etc., for whom the initial cost of plant is proportioned to its horsepower capacity there is little difference apparent between the net cost of producing power in a plant of average cost, and in one of more than or less than average initial outlay. Results of investigations in a large number of plants, of capacity from 100 hp. to 5000 hp., have been averaged and are given in the Practical Reference Tables, some referring to efficiently operated plants using coal as the plant fuel and the others to similar plants using oil. The net cost of power as given in the tables for coal-burning plants, and for oil-burning plants, is for power at the engine, no transmission or conversion losses being considered. These figures are, however, the basis upon which all power costs must be figured and any plant in which such cost is appreciably greater, is not running efficiently and should be carefully overhauled and brought up to the required standard. Plants showing even better results may also be found but they will be rare and operated under conditions that cannot rightfully be taken as typical.

A study of the tables, giving the total net cost of power at the engine per year and per hour for coal-burning and oil-burning steam power plants, respectively, data that is also graphically depicted on the Charts, also in the Practical Reference Table, not only shows the naturally-to-be-expected fact that the cost of producing power varies inversely as the size of the power plant but that there is a "critical size of plant" clearly indicated, the cost of producing power in smaller plants increasing rapidly with any decrease on the size of plant and decreasing much more gradually with any increase ing power-house capacity above the "critical size." Ordinarily, large power plants are operated at greater relative efficiency than small ones. Better management and the greater economical efficiency demanded by the successful operator, the builder and operator of the large power house, explains this fact. The small power house, however, possesses far greater opportunity for efficient operation and should also offer greater incentive for obtaining the most for the least expenditure, even though the same economy in production, as that of the large plant, is impossible.

COST FOR POWER PURPOSES

COST OF power at the engine, though the basis for figuring efficiency, does not represent the total power burden chargeable to any operation requiring power, for conversion, friction and other losses, must be taken into consideration before the cost of power to the machine, lamp or other consumer can be ascertained. Transmission of power is in itself a complicated problem and the cost of such operation can be accurately ascertained only by individual and careful tests.

Usually, however, the useful power output of the engine is either delivered to a main transmission shaft through belts, etc., or is converted into electric energy through a dynamo directly connected to the steam power unit. In the first case, the efficiency of transfer may vary considerably, but, in a well designed plant, with well proportioned pulleys, line shaft, etc., and no unusually long transmission shafts, a horsepower should be delivered to any machine or other consumer of power, on the average, for every 1¼ hp. delivered at the engine, making the average cost for power purposes 25 per cent greater than the cost at the engine.

Referring to the total cost of power at the engine, as given in the tables, as PC, the average net cost of power, as taken from a main transmission shaft, becomes:

Cost per horsepower in dollars. (CHP) = 1.25 PC.
Formula I.

Converting power delivered at the engine into electrical energy through a directly connected dynamo entails somewhat other losses than those incidental to shaft transmission. The combined efficiency of the engine and the dynamo is high, 95 per cent efficiency being obtainable with economic units, the line losses are trivial, in an ordinary size plant, and can be grouped with the losses in the reconversion of the electrical energy into mechanical energy at the machine.

This latter transfer, including the average line losses, entails a further loss of about 15 per cent, so that the cost of electrical energy for power purposes is slightly more than 17⅝ per cent greater than the power cost at the engine, to which must be added the burden of interest, taxes, insurance, depreciation, repairs, etc., of the dynamo and electrical accessories, a burden that

*After an engineering course at Cornell, where he specialized in hydraulics and power-plant design, Mr. Trautschold engaged for 7 yr. in design, testing and erection of motors and generators, elevators, pumps, and special machinery with Sprague Electric Co., Marine Engine & Machine Co. and Henry R. Worthington. Later he acted as designer and in experimental work with Robins Conveying Belt Co., and as general manager for the Intercontinental Engineering Co. Since 1911 he has been engaged in consulting practice on hydro-electric developments and the economics of power production.

averages about 15 per cent of the cost of this supplementary equipment. Expressed in the form of a convenient equation, the average net cost of electric energy for power purposes per kilowatt is:

Cost per kilowatt in dollars. $(CKW = \frac{1.3405 \times PC}{0.95 \times 0.85} + K = 1.66\ PC + K.$ Formula II.

$K = \text{Constant} = 2.25$ per kw.-yr.

$= \frac{2.25}{N}$ per kw.-hr.

N = Total number of operative hours per year.

In an efficiently operated plant, running 10 hr. a day on coal at $3 a ton, CHP would equal $23.04 per year, equivalent to $30.89 per kilowatt-year, or CKW would equal $30.59 per year, provided the Load Factor was 100 per cent—see example—while with a Load Factor of 50 per cent these costs would be about doubled.

Transmission of power electrically in a plant of this size would show a saving of slightly over 1.3 per cent, which introduces another interesting point—the relative value and economy of electrical transmission of power as compared to shaft transmission. The smaller the plant the greater the relative gain—leaving out all question of the greater flexibility and convenience of the practice—in electrical transmission.

The burden of added investment, etc., is nearly relatively constant for any size of plant—slightly greater for the small plant, it is true, but nowhere as much greater as the relative increase in the cost of producing power—so does not form as proportionally large a part of the total cost of electrically transmitted power as it does in the large plant. Furthermore, the small plant is usually subjected to a more constant load factor than the large plant and this has considerable influence on the economical production of power.

Example. Conditions:

Size of plant.....2500 hp.
Plant fuel.....Coal at $3 a ton
Service.....10-hr. day
Load factor.....100 per cent
CHP = 1.25 × 18.43 = $23.04 a hp.-yr., equivalent to $30.89 a kw.-hr.
CKW = 1.66 × 18.43 + 2.25 = $30.59 a kw.-yr.

In charging power costs to any operation, yet another condition has to be reckoned with, that of the mechanical efficiency of the equipment used. Tests are necessary for ascertaining the losses from such causes, for good efficiency for one kind of equipment may be very poor for another. Mechanical efficiency of 80 per cent, that would increase the cost of power as ascertained from Formulas I and II by 25 per cent, might be satisfactory for certain apparatus, while quite inadequate or excessive for machinery employed for other work.

Cost for Lighting

Requirements of adequate and convenient lighting are nearly always met by reliance on electricity and the following study will be based entirely on such illumination. Except for outdoor lighting and the general lighting of foundries, large machine shops, etc., the incandescent lamp is ordinarily employed. Carbon filament incandescent lamps consume from 3 to 3.5 watts per candlepower, while the Tungsten incandescent lamps that are rapidly supplanting the carbon lamp in establishments aiming towards efficiency, consume about 1.5 watts per candlepower.

In the cost of electric lighting, the plant transmitting its power in the form of electric energy has a decided advantage over the plant that has to install separate lighting dynamos, driven from a power shaft, the practice that usually has to be resorted to, for in such plants, about the only expense over that of cost of the current as it is delivered from the plant generator, is the burden entailed by the wiring of the building and the electric light fixtures, which may be neglected, as the expense of such equipment is usually included in the initial cost of the plant; hence, the burden is included in the cost of current. Wiring for electric lighting, however, ordinarily costs from 1½ to 3 per cent of the cost of the building proper, depending upon kind of wiring and grade of fixtures. Current for lighting purposes in plants requiring special conversion of energy must, however, carry the burden of the lighting current generators. Formula III gives the average net cost of electric lighting, both for plants transmitting their power output in the form of electric energy, and for plants in which it is necessary to make conversion from transmitted mechanical energy.

Cost of lighting per year in dollars.

$(CL) = \frac{(A\ PC + B)\ M}{LLF}$ Formula III.

Electric power plants.

A = Constant = 4.6 for carbon filament incandescent lamps.
= 2.3 for Tungsten lamps.

Power plants requiring conversion.

A = Constant = 6.4 for carbon filament incandescent lamps.
= 3.2 for Tungsten lamps.

All types of power plants.

B = Constant = 7.313 for carbon filament incandescent lamps.
= 3.657 for Tungsten lamps.

$LLF = \text{Lighting load factor} = \frac{308\ S}{L}$

S = Operative service hours of plant a day.
L = Total lighting hours required a year.
M = Illumination required in thousands of candlepower.
PC = Cost of power per horsepower-year.

Formula III cannot be easily applied to an electric central station on account of the difficulty in arriving at a true value for LLF, the demands for service from such a station varying greatly, but for the ordinary manufacturing plant, where illumination is required principally during the hours in which the plant load is high, no correction need be made, the results derived from the formula agreeing closely with those attained in efficiently operated plants.

Examples.

1. Conditions:

Size of plant.....250 hp., electric transmission
Plant fuel.....Coal, at $3 a ton
Service.....10-hr. day
Illumination.....10,000 c.p.
Lighting hours, a year.....1000
Type of lamps.....Carbon filament incandescent

$$CL = \frac{(4.6 \times 18.43 + 7.313) \times 10}{308 \times 10/1000} = \$299 \text{ a year.}$$

2. Conditions:

Same as those of Example 1, except that the lamps are of the Tungsten type.

$$CL = \frac{(2.3 \times 18.43 + 3.657) \times 10}{308 \times 10/1000} = \$149.48 \text{ a year.}$$

3. Conditions:

Same as those of Example 1, except that the plant does not employ electric transmission, necessitating conversion.

$$CL = \frac{(6.4 \times 18.43 + 7.313) \times 10}{308 \times 10/1000} = \$406.70 \text{ a year.}$$

4. Conditions:

Same as those for Example 3, except that lamps are of the Tungsten type.

$$CL = \frac{(3.2 \times 18.43 + 3.657) \times 10}{308 \times 10/1000} = \$203.35 \text{ a year.}$$

The examples cited above bring out some interesting facts. First, showing the economic value of the more efficient type of incandescent lamp, a saving of 50 per cent in the cost of lighting being apparent, and the economy of the electrically-operated plant as far as lighting service is concerned—an economy representing a saving of nearly 26½ per cent in the cost of lighting.

The other point of special interest pertains to cost of power for service operation. The relatively small size of the plants considered makes their comparison with a large public service central station unfair, but such comparison is nevertheless of interest. The cost of electric lighting as given by the formula for the plant operated electrically, is equivalent to a flat rate of about 1.5 cents per kw.-hr. This is dependent upon a very high load factor, assumed to be 100 per cent.

Cost for Elevator Service

Elevator service of some kind, for either passenger or freight, is almost necessary in any building and its cost per car mile, the usual unit of measure, can be closely aproximated by a formula. It is true that size and weight of elevator car, its weight capacity, etc., all have some effect on the cost of its operation, but this is not as great as would be expected. Tests of a large number of elevators of various types show that when operated at or near their capacity their power consumption does not vary greatly from 2.25 kw.-hr. (3.0 hp.-hr.) per car mile. Assuming such power consumption as typical and adding a conservative burden for interest on investment, depreciation, and taxes, the average cost of operation is given in Formula IV.

Average cost of operation per car mile in dollars.

$$(CE) = \frac{3.835\ PC + 0.02}{CLF} \qquad \text{Formula IV.}$$

PC = Cost of power per horsepower-hour in dollars.
CLF = Car load factor = proportion of mean load to rated capacity of elevator.

Example. Conditions:
Size of power plant, 2500 hp.
Plant fuel, coal, at $3 a ton.
Service, 10-hr. day.
Elevator load factor, 50 per cent.

$$CE = \frac{3.835 \times 0.005{,}99 + 0.02}{0.50} = \$0.086 \text{ a car mile.}$$

The cost of elevator operation per car mile, as ascertained from the above example, appears high when compared to claims occasionally made by manufacturers of elevators, namely, that the cost of operation will not exceed 2 cents per car mile. In making such claim, the elevator load factor must be taken at 100 per cent; no account made of burden imposed by interest on investment, depreciation that must occur, renewals, etc.; and the cost of power must be based on the exceedingly low rate of ½ cent a hp.-hr., if actual tests on a large number of efficient elevators are to be accepted, some of which tests have been made with the special purpose of showing the high efficiency of the particular type of elevator construction.

Cost of Manufacturing Ice

Artificial manufacture of ice is another operation that modern requirements make of great importance and recent progress in standardization of methods and equipment permits close preliminary calculations to be made of cost of production. Various refrigerating mediums may be employed; either compression or absorption system may be used; the plant may be of the can type or the plate system may be used; but in each case a certain amount of work in the withdrawal of heat from the water has to be done and this can be measured in horsepower.

Carefully conducted tests of the power requirements of a number of efficiently operated ice plants give the average power required to manufacture a ton of ice as 70 hp.-hr. The cost of necessary equipment is nearly the same as that for a steam power house of similar horsepower capacity and a careful comparison of the cost of operation of electrically driven ice plants and those operated on steam power, shows practically no difference in net cost of production. The electrically operated plant, however, is ordinarily the more convenient. The average cost of producing a ton of ice in an efficient plant may be directly calculated from the Power Cost tables and Formula I; see Formula V.

Cost of manufacturing one ton of Ice in dollars.

$$(CI) = \frac{70\ (1.25\ B + B)}{N} + \frac{70 \times 1.25\ (E + F)}{308 \times S} =$$

$$\frac{157.5\ B}{N} + \frac{0.284\ (E + F)}{S} \qquad \text{Formula V.}$$

B = Yearly Burden (Power House capacity = 70 × Ice tonnage capacity.)
= Item C in Table for Coal-Burning Plant.
= Item C in Table for Oil-Burning Plant.
E = Operating Expenses, attendance, supplies, etc.
= Sum of items D or E and F or G in Table for Coal-Burning Plant.
= Sum of items D or E and F or G in Table for Oil-Burning Plant.
F = Fuel Expenses.
= Item H or I in Table × unit cost of fuel for Coal-Burning Plant.
= Item H or I in Table × unit cost of fuel for Oil-Burning Plant.

N = Total number operative hours of plant a year.
S = Service hours of plant a day.

Example: Conditions:
Size of ice plant, 25.7 ton, 2500 hp.
Plant fuel, coal at $3 a ton.
Service, 10-hr. day, 200-day year.

$$CI = \frac{157.5 \times 8.53}{2000} + \frac{0.284\ (3.05 + 0.55 + 2.1 \times 3)}{10} =$$

$0.9529 a ton.

In the example cited above, it will be noted that the cost of producing a ton of ice is more than twice that for the power consumed, figuring on the assumption that the ice plant was running at its capacity during all operative hours.

Cost for Refrigeration

Mechanical refrigeration for cold storage is nowadays of almost greater importance than the manufacture of artificial ice and is an operation that, though similar to that required for the manufacture of ice, is more efficient and more easily figured upon. The operative hours are more constant, in fact may be considered as continuous, and the requirements for power also more constant, for there is in reality comparatively little difference in the cost of operating a refrigerating plant winter or summer—explained, in part, by the fact that buildings suitable for refrigerating purposes must be so well constructed that heat leakage to the cold storage rooms is kept at a minimum, thus tending towards uniform conditions. Various commodities require different degrees of refrigeration, but measure of refrigeration, expressed as tons of refrigeration or similar unit, is constant, involving a specific consumption of power for its realization. A ton of refrigeration requires the withdrawal of 288,000 B.t.u. for 24 hr. operation, the latent heat liberated in the melting of one ton of ice. This requires the use of but about 35 hp. as shown by the average of a number of efficient ice plants, withdrawal of heat being from the atmosphere, thus avoiding the necessity of taking up the latent heat of any substance as in the manufacture of ice, and the lowering of temperature is constant. Taking the consumption at 35 hp. per ton of refrigeration as typical of efficient operation, the cost per ton of refrigeration in a plant of any specific size, when the burden of investment in refrigerating apparatus is about equal to that for power generating equipment, is expressed in Formula VI.

Cost of one Ton of Refrigeration in dollars. (CR) = $\frac{35\ (1.25\ PC + B)}{365 \times 24} = 0.005\ PC + 0.004\ B$. Formula VI.

B = Yearly Burden of refrigeration equipment.
= Power House Yearly Burden, Table for Coal-Burning Plant, also Table for Oil-Burning Plant.

PC = Power Cost per horsepower-year in dollars.

Example. Conditions:
Size of power house, 2500 hp.
Plant fuel, coal at $3 a ton.

CR = $0.005 \times 28.55 + 0.004 \times 8.53 = \$0.17\frac{2}{3}$ a ton of refrigeration.

Though 17⅔ cents would represent about the net cost of producing 1 ton of refrigeration in an efficient 2500-hp. plant, it cannot be taken as a measure of the net cost of refrigeration, for the leakage of heat through the walls, ceiling and floor of the cold storage room (its surface) may be at quite varying rate in 2 similar plants. This coefficient of heat leakage, in some efficient refrigerating plant, is as low as 1 or 2 B.t.u. per sq. ft. of surface per 24 hr. per degree difference between internal and external temperatures, while in others, not as efficient plants, of course, it may be as high as 10 or 12 B.t.u. A heat leakage of 1 B.t.u. each 24 hr. per sq. ft. of surface per degree from a cold storage room of 10,000 sq. ft. surface at a temperature difference of 30 deg., would represent a daily loss of 300,000 B.t.u., equivalent to over a ton refrigeration, while a 10-B.t.u. loss from a similar cold storage room, under similar conditions, would entail a daily loss 10 times as great.

Cost for Heating

The "power cost" tables may be used for closely ascertaining the average cost of heating by steam, provided the square feet of radiation required is known or the volume of space to be served and the mean outdoor temperature during the "heating months." The heating problem is in certain respects simpler than the power problem, for the combustion of a certain amount of fuel liberates a definite amount of heat, about 60 per cent of which can be delivered at the radiator irrespective of the size of the heating plant. Power production, on the other hand, requires the consumption of nearly 7 times as much fuel in a 100-hp. plant as in a 5000-hp. plant for the development of the same power, both plants being operated to their capacity. The intial cost of a heating plant is relatively less than that of a power plant but the relative expense for attendance, supplies, etc., does not vary to any great extent. A heating plant of specified size will carry a yearly burden, dependent upon initial cost, about proportionate to that of a power plant (24 hr. service) of similar fuel requirements; i.e., the initial cost of the 2 plants varying about as their respective fuel requirements. In other words, the net cost of power per hour in a plant of fuel burning (normal) capacity equal to that required for the heating plant multiplied by the number of hours that heat is required, will give the annual net cost of heating, including the burden of interest on investment, taxes, insurance, etc., as well as the expense for fuel and attendance —the only correction to be made being that for rate of fuel combustion.

The relationship existing between the square feet of heating surface and the number of cubic feet of space heated may be safely and conservatively taken as 1:90. That is, 1 sq. ft. radiation surface is required for each 90 cu. ft. of space. The heat required to raise the temperature of a building to 70 deg. in zero weather, equals 250 B.t.u. per sq. ft. of radiation surface, and the heat requirements with other outdoor temperatures, varies directly with the difference between interior and exterior temperatures. Such relationships permit the direct reference to the "Power Cost" tables for simple calculation of the annual net cost of heating under any conditions, the mean consumption of fuel per hour by the heating plant equalling the normal hourly fuel consumption of a power house of corresponding capacity; the annual cost of heating then equalling that of operating the power plant for the number of heating days—see Formulas VII, VII-a and VIII.

250 B.t.u. is equivalent to 0.000,018 tons of coal (average) or equivalent to 0.001,440 gallons oil fuel (average).

$$\text{Mean fuel requirements of heating plant} = \begin{cases} \dfrac{0.000{,}018\ R\ (70 - t)}{70} \\ \dfrac{0.001{,}440\ R\ (70 - t)}{70} \end{cases}$$

$= 0.000{,}000{,}257\ R\ (70 - t)$ tons, coal, per hour.
$= 0.000{,}020{,}570\ R\ (70 - t)$ gallons, oil fuel, per hour.

$HP \times Y = 0.0019\ R\ (70 - t) = 0.1710\ Q\ (70 - t)$—Coal-Burning Plant. Formula VII.

$HP \times Y = 0.1520\ R\ (70 - t) = 13.689\ Q\ (70 - t)$—Oil-Burning Plant. Formula VII-a.

$$Y = \begin{cases} \dfrac{0.0019\ R\ (70 - t)}{HP} & \text{Coal-Burning Plant.} \\ \dfrac{0.1520\ R\ (70 - t)}{HP} & \text{Oil-Burning Plant.} \end{cases} \qquad V = \text{Factor} = \frac{Y}{F}$$

Y = Mean horsepower fuel requirements of heating plant (hourly req.).
F = Normal horsepower fuel requirements of equivalent power plant.

$CH = 24 \times HP \times PC \times N \times V$. Formula VIII.

CH = Annual cost of heating in dollars.
HP = Horsepower derived from Formula VII or VII-a.
PC = Cost of 24 hr. power in plant of hp. capacity per horsepower in dollars.
N = Number of operative days of heating plant per year.

Examples:

1. Conditions:

Radiation required.....160,000 sq. ft. = R
Mean outdoor temperature.....35 deg. F. = t
Heating days (24 hr.) per year.....201 = N
Fuel .....$3 per ton
$HP \times Y = 0.0019 \times 160{,}000 \times 35 = 10{,}640$. Formula VII.

Referring to Table for Coal-Burning Plants, HP = 2500, Y = 4.256, V = 1.0133, $CH = 24 \times 2500 \times 0.003{,}86 \times 210 \times 1.0133 = \$28{,}004.48$ per year.

2. Conditions:

Same as those for Example 1, except that radiation required is but 32,000 sq. ft.

$HP \times Y = 0.0019 \times 32{,}000 \times 35 = 2128$. Formula VII.

Referring to Table for Coal-Burning Plant, HP = 100, Y = 21.28, V = 1.064, $CH = 24 \times 100 \times 0.013{,}33 \times 210 \times 1.064 = \$6{,}150.08$ per year.

The formulas pertaining to heating operations, like those for power, are dependent upon the use of high grade equipment, upon the use of suitable fuel of good grade and efficient operation, and under such conditions are conservatively accurate for any size of undertaking. Cases exist, however, where it is impossible to obtain fuel for the requisite quality, and in such instances greater accuracy may be arrived at by separating the expense of fuel from the cost of power as given in the "Cost Tables" and correcting for this main expense in heating operations. The Tables give the fuel requirements of various sizes of power plants and set the standard for efficiency. If these results cannot be obtained the item of fuel expense entering the Tables for the total cost of power should be corrected, making the formulas applicable to any conditions.

In plants using exhaust steam for heating purposes, no modifications of the formulas need be made for plants operating efficiently. The use of exhaust steam for heating is but the use of energy that might be used for power purposes and it makes very little actual difference in net cost of heating whether the energy so used is taken from the boilers, before passage through the power units, or from the exhaust of the engines before it has accomplished its maximum of productive work.

Cost for Pumping

Pumping of water for domestic consumption, for fire protection and for numerous industrial purposes is an operation of much general interest, the cost of performing which may also be closely calculated from the "Cost Tables." Ordinarily the measure of the work performed by a pumping engine or pump is referred to as its "duty," the accepted measure being the foot-pounds of work performed per million B.t.u. supplied, which, though accurately fixing the efficiency of the pump, does not convey much information as to the cost of delivering the water.

To arrive at a basis upon which to figure costs, then, it is necessary to consider only the pump of average efficiency and to consider the relative "duty" of pumps as dependent upon the efficiency of the power house operation by which they are driven. The quantity of water pumped and the head against which it is raised govern the power requirements, the former affecting the relationship directly, within the range of the pump, and the latter governing largely the efficiency of the pump. The efficiency of reciprocating and that of centrifugal pumps are affected quite differently by the head, but their efficiency is about co-ordinate at 30-ft. head, which is also about the head of the average installation. Therefore, such efficiency may safely be taken as typical of the large majority of pumps for the operations under consideration. With such efficiency, the power requirements for pumping become equal to about QH/2500, where Q equals the number of gallons of water pumped per minute and H the head in feet, such requirements being usually continuous—that is, pumping stations are customarily operated 24 hr. each day. Such power may be supplied from a large power plant in which the balance of power generated is used for other purposes or may be supplied from a comparatively small plant delivering power for pumping operations only.

The burden imposed by a pumping installation is very nearly the same as that of a steam power plant of a power capacity equal to the power requirements of the pumping station. Expressing these relations in terms of data contained in the "Cost Tables," the net annual cost of pumping is given in Formula IX.

$CP = 0.0004\ QH\ (1.25\ PC \times N \times S + B)$ Formula IX.

CP = Annual cost of pumping in dollars.
Q = Quantity of water pumped in gallons per minute.
H = Head (total) against which water is pumped in feet.
PC = Cost of power per horsepower hour.
N = Number of pumping days per year.
S = Service of pumping station, hours per day.
B = Burden (yearly) of pumping station in dollars.
= Sum of items in Table, columns C, D, E, F and G, for a station of 0.0004 QH horsepower capacity—Coal-Burning Power House.
Or sum of items in Table, columns C, D, E, F and G, for a station of 0.0004 QH horsepower capacity—Oil-Burning Power House.

Examples:

1. Conditions:

Water required.....5000 gal. per min. = Q
Head .....50 ft. = H
Size of power house.....2500 hp.
Service .....24 hr. = S
Operative days per year.....300 = N
Fuel.....Coal at $3 per ton

$CP = 0.0004 \times 5000 \times 50\ (1.25 \times 0.003{,}86 \times 300 \times 24 + 26.66 + 24 + 5.76)$
$= 100\ (34.354 + 51.42) = \$8{,}577.40$ per year — $3.97 per million gallons.

2. Conditions:

Same as those for Example 1, except that service is for but 10 hr. per day.

$CP = 0.0004 \times 5000 \times 50\ (1.25 \times 0.005{,}99 \times 300 \times 10 + 26.66 + 12 + 2.40)$.
$= 100\ (22.4725 \times 41.06) = \$6{,}353.25$ per year — $7.06 per million gallons.

3. Conditions:

Same as those for Example 1, except that service is for 24 hr. every day and that the pumping station is operated by a 100-hp. power house.

$CP = 0.0004 \times 100 \times 50\ (1.25 \times 0.015{,}75 \times 365 \times 24 + 26.66 + 24 + 5.76)$
$= 100\ (172.4625 + 51.42) = \$22{,}388.25$ per year — $8.05 per million gallons.

The foregoing examples well illustrate the relative financial value of widely differing water supply service. The first example is typical of a large industrial enterprise requiring a great volume of water continually or a "public service company" having sufficient storage capacity to remain inoperative 65 days each year.

Example 2 is typical of an industrial plant operating 10 hr. a day and requiring a large supply of water during operating hours only, depending upon tank storage for use during stand-by hours. Such a plant would spend but about 75 per cent as much for pumping service as one operating 24 hr. a day, but the net relative cost of pumping would be about 78 per cent higher.

Example 3 is typical of a pumping station for a small community, one that performs no other service than that of furnishing a continuous supply of water. Such a plant would cost about 2.6 times as much to operate as the pumping station of Example 1, but the relative net cost of water supply would be at a rate about twice as high.

The various operations that have been considered and the derivation of the formulas applicable to each case, serve to show practical application of the "Power Cost" tables, the monetary basis for all operations involving the use of power. The cost of any operating consuming power, or energy that can be measured in terms of power equivalent, can be similarly ascertained. A measure of the power requirements, the mechanical efficiency of the apparatus employed and its initial cost—about 15 per cent of which will usually cover all items of equipment burden, depreciation, attendance, etc.—is all that is required for a practical application of the "Cost Tables" to any undertaking.

In addition to these requirements, however, knowledge of the "Load Factor" is necessary and this can only be accurately arrived at by careful investigation of operating conditions. Having ascertained the average "Load Factor" in per cent, approximately accurate results are attained by simply dividing the cost obtained from a formula by the "Load Factor."

Piping Dimensions

RULES FOR DETERMINING THE SIZE OF STEAM AND EXHAUST PIPES OF ENGINES

WHEN determining the size of a steam main, a velocity of from 6000 to 8000 ft. a minute is generally accepted as standard practice, although velocities as high as 12,000 ft. a minute have been used in large power plants. For exhaust pipes a velocity of 4000 ft. a minute is a safe working figure.

In determining the size of the steam and the exhaust piping for a given engine, it is usually considered that it takes steam the full length of the stroke, therefore the length of stroke and piston speed must be known as well as the area of the cylinder. Having obtained these figures, multiply the area of the cylinder in square feet by the piston speed in feet per minute, which gives the volume in cubic feet to be filled with steam each minute. This product divided by the velocity of the steam and multiplied by 144 gives the required area of the pipe in square inches. To figure the area of the exhaust pipe, the problem is solved in the same manner with the exception that the exhaust velocity is substituted for the steam velocity.

We can express these rules in the shape of a formula as follows: $\frac{A \times S}{V} \times 144$, in which A = cylinder area in square feet, S = piston speed in feet per minute, and V = steam velocity in feet per minute.

As a practical illustration, assume that it is required to find the sizes of pipes for an engine with a cylinder diameter of 12 in. and a stroke of 24 in., operating at 80 r.p.m. Area of cylinder square feet $= (6^2 \times 3.1416) \div 144 = 0.78$. Piston speed in feet per minute $= (80 \times 2 \times 24) \div 12 = 320$. Assume a steam velocity of 8000 ft. and an exhaust velocity of 4000 ft. a minute, then the area of the steam pipe in square inches will be $\frac{320 \times 0.78}{8000} \times 144 = 4.49$ sq. in. The area of the exhaust pipe in square inches will be $\frac{320 \times 0.78}{4000} \times 144 = 8.98$ sq. in.

THE FEDERAL CLAY PRODUCT CO. is arranging to build a central power house and operate its factories at Mineral City, Ohio, by electricity. It is said that the plant will be 1000-hp., with the latest engines and boilers, with all the latest improvements, including stokers and water purifying apparatus. The proposed new factory will be of much larger output than the one that was lately destroyed by fire and will be one of the most up-to-date brick factories in the state.

The Organization

FIXING RESPONSIBILITY FOR WORK AND CARE OF APPARATUS

IN any plant there should be a definite realization of the proper division of work and responsibility and definite apportionment of these. It is always useful to arrange the plan of work as if for an organization where the force is of sufficient size to make staff organization desirable; then assign the functions of the staff among the members of the force. This is not for the sake of creating titles, but as a means for defining and placing responsibility and clarifying ideas; the fact that one man may perform the duties which, in a large force, would be divided among several, does not lessen the value of making the plan, for it is desirable for such a man to departmentize his work, and keep in mind the reason for and duties of the departments he is handling to make sure that none are neglected or slighted.

DIVIDING RESPONSIBILITY

STAFF DIVISION means the separation of work into divisions, each one of which receives special attention from a man who is in charge of it and who acts as expert adviser and investigator in that line. It is the function of the chief to plan methods, study results, decide matters of policy and responsibility and maintain discipline. His staff should carry out his instructions, report progress and results, suggest and advise on methods in their specialties and supervise the work of the men under them. The force are to execute the work, and though co-operation and suggestions from them should be encouraged, they should not be burdened with responsibility beyond that for the performance of their own definite work, according to instructions given.

While efficiency means better results, and closer attention, it does not mean strain and hurry. It involves the placing of responsibility for results where it belongs on those who are paid for taking it, elimination of useless effort and keeping after a definite, known, high, but entirely possible, standard of performance.

A natural division of staff responsibility is into Boiler Room Superintendence; Steam Machinery, Electrical Equipment. The Boiler Room Superintendent would have charge of making steam, and all apparatus involved in the process, and is the most important member of the staff, as his department can make more difference in the efficiency of the plant than any other. His domain covers the coal pile, boilers and furnaces, feed pumps, draft apparatus, heaters, economizers and measuring and recording apparatus used with these. The Steam Engineer will have charge of the steam transmitting system and all steam-using machinery and allied apparatus, including piping, engines, turbines, traps, separators, condensers, lubrication system, refrigerating apparatus, compressors, and the measuring and recording instruments accompanying these; also heating and ventilation apparatus, house water supply, fire pumps and all other auxiliaries except boiler-feed pumps, blowers or exhausters for mechanical draft and stoker engines if used.

To the Chief Electrician will fall the responsibility for generators, transmission lines, motors, transformers, switchboard and switching apparatus, batteries, converters and all other electrical apparatus. Evidently responsibility for the operation of many of the motors will not be a part of his duties, but their installation, upkeep and condition should be alloted to him.

Assignment of working force to each staff member will be evident from the machinery for which he is responsible. The duties of 2 members of the staff may be assigned to one man, where the force is small, or it may be that the Chief will have to be his own staff and adviser, but separation of the plant operation into the 3 divisions indicated is always helpful in systematizing records, planning for tests, eliminating losses and locating responsibility for trouble.

In subdividing the work among the force, there should be the same clear definite placing of responsibility for each duty and piece of machinery. To one may be assigned boilers, stokers or furnaces, firing, draft apparatus and regulation, coal records, draft records, gas analysis, furnace and flue gas temperatures; to another may go the boiler feeding, pumps, piping, heaters, records of water supply, feed temperature, economizers, calorimeter tests and steam flow from the boiler. Or one man may be given all the duties in regard to both coal and water supply. But each class should be kept by itself in instructions, inspection tests and records in order to give a systematic relation.

In larger plants, the boiler-room operations will naturally divide into coal supply, firing, and draft regulation, water tending, cleaning, and the keeping of records and routine testing. But whatever the division, if the greatest efficiency is to be attained, each operation must be studied to find the best way of doing it, instructions for this best way put into permanent form, the method taught to the man who is to do the work and his interest secured in producing the maximum return for the minimum effort. The beginning is best made at the point where conditions are most satisfactory, getting that part of the work, or that operation up to as much better performance as possible with the means at hand or obtainable. Then go on to the next operation or method that needs improving, and so on. One thing at a time, bettered until the whole plant has been gone over. Then take a survey and determine the point for beginning the next stage of betterment. Be not satisfied with yourself nor dissatisfied with present equipment until you have made the best possible use of what you have.

EMPLOYING MEN

IN REGARD to handling the men, the last preachment applies, especially. Be not dissatisfied with a present member of the working force until you have made the best of him; first, by getting him at the work for which he is best fitted; second, by teaching him all you can

about his work; third, by using every effort to arouse his interest and enthusiasm. The chances are that by the time this has been done, you will find all the force valuable men to keep.

When there is a vacancy to be filled, it is more important to get a man with the right characteristics for the work than one who has had great experience in that particular line. A man who abhors system, is unwilling to accept the ideas of others and "hates figures," is surely not suited for a keeper of records and data. A forgetful sluggard cannot be made into an alert fireman. But the water tender or coal passer who is eager to learn and keen to observe can readily be taught the essentials of getting good results in firing, if the accumulated experience of the plant is at his disposal in the form of instructions and records.

The vacancies to be filled from outside the force should always be at the bottom, those higher up being filled by promotion, and each man being always encouraged to fit himself for the position next above him. The spirit of civil service—insurance of permanency of employment, periodical tests of fitness for promotion, and a system of increased pay for proved increase in effectiveness are great aids in securing loyalty, meeting any emergency that may arise and building up an organization. Direct, frequent personal contact of the chief with each man in the force and sympathetic insight into his problems means much to the chief in his management of the plant and the men, and to them in their development. This is best secured by daily visits throughout the plant to inspect, discuss and check up the work in progress. Such visits serve also to emphasize the real earnestness of the chief's purpose to maintain a high standard of performance and to profit by suggestions from any source for improving the conditions of the plant and the employes.

Duties of Employes

CHARACTER OF MEN FOR IMPORTANT POSITIONS, RELATIVE RESPONSIBILITY; ROUTINE OF WORK IN A FACTORY PLANT. BY WILLIAM S. TROFATTER*

IN the operation and maintenance of a power plant the crew should have specific duties to perform and regular times for each job, barring, of course, accidents which require their services at such times, and which for the time being are of more importance than routine work. The watch engineer should be held strictly to account for everything during his hours of service, he should be given full authority, and all men employed in the power plant should understand he is responsible and that his orders are to be carried out without argument; all work should be systematized, each man having regular parts of the work to do or to see that such work is properly attended to, and it will be a good plan for the chief engineer to keep close watch of a new member of the crew until a good line is had as to the man's ability and resourcefulness in case of accident or emergency, which will call for quick and decisive action.

Watch engineers should be men of good judgment, cool in face of danger, and should not send men where they would not go themselves. Every employe should be required to be on duty at his regular appointed time and attend strictly to his particular work; no favorites should be played or suckers tolerated, as one man tattling will disrupt a whole crew in a short time. Men should be taught to mind their own business, attend strictly to their own affairs, and all trouble makers should be immediately removed from the service, for the good of the loyal employes.

REGULAR INSPECTION

ESSENTIAL RULES should be made and placed where they can be readily seen and read; they should be few, but mean exactly what they say and should be rigidly enforced. Regular inspections of all apparatus should be made; boilers should be regularly washed out, combustion chambers and shells thoroughly cleaned and brushed; handhole plates examined for leaky gaskets which will corrode tube sheets, leaky tube ends, and shells looked over for fire cracks especially on girth seams over bridge walls on return-tubular boilers; internal feed pipes broken or loose, loose or broken braces and corrosion or pitting at water line in either tubular or water-tube boilers. Steam gages should be tested regularly and safety valves should be lifted from their seats daily.

In operation, water should be carried at a fairly uniform level and fireman should be instructed to fire light and often covering only one side of furnace at a time; soft coal should be fired on an opening damper, so as to allow coal to burn off gases before automatic damper has closed, and hand damper should be partly closed for economy. Pumps should be inspected at regular intervals for defective piston or rod packing or badly worn or cracked water valves, and regular stroke measurements should be taken of all direct-acting steam pumps, in order to maintain full stroke conditions, as they use the same amount of steam (practically) on short as on full stroke but do not pump the proper amount of water.

Feed water heaters require considerable attention at times, especially the open type which should be cleaned regularly and all filtering material changed often to prevent oil from going over to the boilers. All steam main and branch main pipes should be thoroughly drained and all such drains regularly and thoroughly inspected to be sure they are performing their full duty and keeping mains free from water.

Engines should be frequently gone over and cylinder heads removed at least every 9 months and rings and springs looked over and piston properly located central with counterbore, sharp edges removed from rings and

*Experience as chief engineer in plants of nearly every description has given Mr. Trofatter a broad view of plant management. Starting with 3 yr. in the machine shop, he graduated into the power field as engineer for Rogers Shoe Co., and later, to gain wider experience, went with the Murphy Estate at Beverley, Mass. A list of later positions as chief engineer in charge of construction and operation of plants tells its own story: Philadelphia & Reading Coal & Iron Co., at Salem; Salem Building Association; J. H. Poor & Co.; Eureka Silk Mills; Danversport Rubber Co.; Mass. Broken Stone Co.; Shepard, Norwell & Co.'s Store; Hutchings-Votey Organ Co., for whom he designed and installed a complete steam and electric plant; Marlboro Electric Co.; Warner Cotton Mills; and since 1909, chief engineer of the Loose-Wiles Biscuit Co., of Boston.

condition of cylinder bore carefully noted; valves should be looked over and adjusted if necessary. Externally, engines should be gone over daily, for loose set screws or locknuts, loose oilers or cotter pins in automatic oiling devices, and at least once a week lock or jam nuts on piston rod at crosshead should be tested for tightness if a threaded rod.

Generators should be looked over often for loose connections, broken brush holder spring or defective brush contacts, loose switchboard connections or dirty switch blade connections.

Duties of Each Shift

Perhaps this matter can be made somewhat more clear by stating conditions in a plant over which the writer has charge, consisting of 4 tubular boilers, with regular feed equipment, open heater, vacuum heating system, fire pump and sprinkler system, Corliss engines, 3-wire generators, high speed engine and ammonia compressor for refrigerating system and a brine circulation system, all in a large manufacturing plant running 20 to 24 hr. a day. There are 3 watch engineers on 7-day, 8-hr. service, and firemen and helper in boiler room, laborer for cleaning back connections to boilers, etc., electrician and steam-fitters, etc. There are 4 engines, 3 of which are Corliss and one a high speed, and the watches are 7 a. m. to 3 p. m., 3 p. m. to 11 p. m., and 11 p. m. to 7 a. m. The first watch cares for switchboard front, keeping it clean, caring for and keeping all circuit breakers and switch contacts clean and in good electrical contact, cares for recording gages and changes charts on them, looks after and winds wall clocks, cares for and polishes gages and small engine, and cares for oil filter on oiling system. It also, of course, has charge of operation and makes such minor repairs as may become necessary on this watch. The second watch cares for and keeps clean one of the Corliss engines, has the care and maintenance of water pistons and rod packings on boiler feed, sump well and brine circulation pumps and also all force-feed lubricators, and hydrostatic cups, the latter not in continuous use and only used in case of failure of the force feed apparatus. The third watch, has the care of 2 Corliss engines, and looks after the vacuum pump and salt water and drinking water circulation pumps.

Care of engines spoken of above means that they are to be thoroughly looked over and cleaned and all brass and bright work is to be kept polished only by the man who is held responsible for the condition of his designated engine. Each engineer assuming a watch has to sign a service slip (after personal inspection), which is made out by the man being relieved, stating condition of bearings, oiling system, steam pressure and boiler room conditions, and after he has signed such slip he is held personally responsible until relieved by the next watch engineer. Should he, however, find bearing running hot or anything not as it should be, it is his privilege not to sign the slip until engineer going off watch has stated actual conditions under head of remarks, and which, of course, shifts the blame to the man on whose watch the trouble commenced.

Regular routine is as follows: Except in case of emergency, no engine may be started until oiling system has been turned on, sight feeds looked over to be sure they are feeding properly, valve gear oiled and engine thoroughly warmed up. When in service, all bearings and feeds must be inspected every 12 min. (engines run 150 r.p.m.) and when stopped all engines must be left off centers ready to start if needed. Engines are indicated regularly for valve gear slippage or wear and piston rods are gone over for wear of crosshead shoes every month to make sure they are parallel with the slides. Dashpots are washed out once a week with kerosene as are also the telescopic oilers on crossheads and eccentrics and the centrifugal oilers on crankpins. Telescopic inside pipes should be examined frequently and replaced when worn thin.

Close Attention and Knowledge Demanded

Men on watch are not allowed to read or to do anything except such work as comes on their tour of duty, but no objection is made to men sitting down as long as their mind is on their work and nothing is being neglected. Every employe of the engineer's dpartment is requested to ask for any information about anything in the plant and told plainly that no excuse on account of ignorance of operation will be entertained and all seekers for information employed in the department are treated courteously and the matter fully explained to them with the fact thoroughly impressed upon them that we are glad to know that their interest is strong enough to want to become more familiar with the machinery and they are encouraged to become more capable, not only for their own good but they, of course, are more reliable and of more value to the company.

The electrician makes daily inspections of generators, and every week looks over the back of the switchboard for loose or defective connections, etc. Oil level in transformers is examined semi-annually, and such as has evaporated is replaced.

The day fireman, besides caring for his fires, looks after his pumps and keeps them clean; most of his time he is busy on his fires and he has little time for anything else. The night fireman cleans fires every night and on 3 boilers in service scrapes tubes in one boiler one night, blowing all 3 the next night then scraping next boiler and so on, each boiler being blown every other night and scraped once a week. A laborer employed, scrubs the engine room floor daily and cleans all combustion chambers when boilers are down, as we find this more economical than attempting to do such work with fireman and the consequent neglect of firing duties that necessarily ensues.

In the boiler room, safety valves are lifted every morning, all boilers blown down slightly, all water columns, gage glass conections and furnace mouth protectors thoroughly blown out every morning and all gage cocks are tested at the same time; traps on steam mains are examined every day and a scheme we make use of and a good one for any make of float trap is to leave the air cock slightly open for 2 reasons, first, that it prevents the trap from becoming air bound, and the second, that, should a float collapse or valve get stuck, the air cock as soon as trap becomes full will allow water to run out on the floor, thereby calling attention to the trap so that the bypass can be opened and the trap taken out for repairs. Feed water heater is of open type with 2 oil separators in the exhaust line, the heater being piped as an induction heater. Filtering material is changed, when using returns, at least once a month, excelsior and coke being used, care is used when cleaning

not to let any filtering material get below the plates in the heater as it will pass over into the suction line and give no end of trouble by getting under suction and discharge valves of pumps and also under check valves in feed lines. Vent and safety valves are kept in good order, also the vacuum breaker, all of which is tested every day and takes only a couple of minutes each time.

All men employed in the department are required to make a report on all troubles and repairs necessary to be made, and on all repair jobs, a careful account is kept of labor and material.

All oils are carefully measured and placed on an account sheet every day, as is also all waste, and the number of hours run, together with a load reading on electrical units every 30 min., and wattmeters can be checked by these half-hourly readings, and come very close, if meters are fairly accurate.

General Rules of the Plant

A few simple rules that apply at this plant and which are adaptable almost everywhere are as follows:

1. We require absolute honesty from every employe.
2. No man will be allowed to come on duty with liquor in, on, or about him, or to procure or use it while on duty.
3. Any employe allowing his relief engineer or fireman to come on duty under the influence of liquor, and who does not immediately report him or cause him to be reported, will be dealt with as unreliable and will be discharged.

These are about all that are needed except such instructions as may apply to any individual plant, but the conditions not being identical examples are of no use except to the one plant for which they were made.

I believe a spirit of cooperation should be prominent and can be successfully encouraged by the chief engineer if he be a man of good even temper; when a mistake is made, endeavor to show the man his error and reason with him rather than to call him down for something for which he is, perhaps, not entirely to blame. Many men, if given a helping hand, will become enthusiastic workers and make rattling good men; but the man who thinks the world is down on him and cannot see any sunshine at all, should be sent to the boneyard as he has only the funeral spirit and that has no place about a modern power plant, where the optimistic person is the man for the position.

Practical Training of the Operating Engineer

General Course Mapped Out for the Young Engineer. By William D. Ennis*

THERE is a tendency, nowadays, in all of the mechanical trades, toward specialization. Good all-round machinists are becoming scarce. Instead we find men broken in to do some one job or set of jobs with exceptional speed. There is an economical advantage in this, and the disadvantage is not so immediately apparent. In the power plant, however—or at least in the great majority of plants, which are, of course, small— this tendency to specialization must be resisted. If suitable men are to be forthcoming for economically managing power operation, these men must have an all-round training in the great variety of work which is encountered even in the simplest boiler room.

Good training implies systematic training, but system is sometimes overdone. One man will have a card system of instructions for every conceivable job about the plant. Another will keep his books and records in his head. Most engineers follow a middle course. In the larger plants, where it is desired to advance good men rapidly, some amount of "red tape" is probably justifiable. Written (or printed) instructions, and standing orders, will save time and supervision where a man does certain pieces of work rather infrequently.

Again, such "standard practice" instructions are likely to train the learner in the habit of reflecting over his work, both before and after doing it. Suppose an instruction card covers a matter like packing the feed pump rods. The apprentice should be shown how to do it first. Then let him read the card, pack the rods and read the card again. At this time he is qualified to ask intelligent questions. Perhaps later on he may make suggestions for improvement which will be worth incorporating into standard practice.

Laying the Foundation

The proper approach to any system of training in the incidental work of the plant is by way of a schedule. As soon as a greenhorn enters the engine room he is directed to keep the oil cups filled. His first intelligent action thereafter is to note how often refilling is necessary. He learns that some cups require more frequent filling than others. If of an inquiring mind, he finds out why. The best service his chief can do him at this point (after seeing that he does his work), is to encourage such questions and to answer them carefully. It is a fine quality always to give a serious and well-considered answer, without the assumption of too much knowledge, to a question rightfully asked.

Many things adjust themselves to a schedule almost automatically. The intervals between packing grease cups, or between the hand oiling of parts of a Corliss valve gear, soon become established. Then at a later date comes the equally regular routine of inspection. This covers not only that invisible inspection which goes on all the time, on the part of a good chief engineer, as he walks through the plant with his hands idle, but also those regular examinations for safety, wear or service which experience times in each plant. A regular schedule of inspection, rigidly adhered to and never skimped through the press of work, will impress the assistant in many ways.

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Repairs and Supplies

Whenever anyone attempts to evolve a classification of power plant costs he at once meets the difficulty of drawing a fine line between repairs and supplies. A new boiler tube is a repair and oils are supplies; but what are gage glasses, or asbestos plugs or manhole packings? From an operating standpoint, there is something to be said in favor of a plan which lists all materials regularly entering into operation, consumed in service and replaced periodically, as supplies. Other materials, which fail by accident, or in emergencies, are repairs. Now, this distinction suggests a point in the training of the operating engineer which may be overlooked. There may be systematic inspection, a systematic arrangement of regular incidental work, and systematic distribution of that work among the various assistants. But it is not easy to plan in advance for emergency conditions. To take a simple occasional case, no one can foresee a broken belt. A man might serve his time in a plant and take charge in another place without having ever met with that particular emergency. Yet emergencies and unusual repairs are the very things in which the experience, skill and judgment of the plant operator count most. What possibility is there of giving a man the necessary training in handling emergency conditions?

Several answers are possible. A joker might suggest that it would not be difficult for the young engineer to locate for a year or so in some plant where emergency repairs were needed almost daily. There are such plants in all parts of the country. Again, a long period of training—beginning with a well-grown boy of, say, eighteen, and lasting a full 5 yr.—would be likely to develop most of the common emergencies. As a practical suggestion under this arrangement, let the boy spend a good share of time in each part of the plant, and let him have a regular alternation of hours (if the plant runs day and night) but as subordinate and in charge for the time being. If even then he does not meet with all the conceivable emergencies of plant operation, we can only say that we are training him to think for himself, not to copy blindly, so that when something new confronts him he may possibly have the grit and intelligence to find the right way out for himself.

The chief engineer must remember that the apprentice is not quite in the position of a boy in school. The right kind of young man will want to learn, of course, but his main object is to make a living. That is what he is there for. If he has learning exclusively in view he would probably go to school. An essential part of an operating engineer's training is to show him that intelligence and efficiency are recognized by rewarding those traits when they appear. It pays to pay a good man well and to pay an improving man liberally. Only let him see a direct connection between his efficiency and his salary. Few things are more important than to make a distinction in pay between the man who is really efficient and the man who merely gets through the day's work. In plants where wages are standardized (as they probably must be in large plants), the exceptional man cannot be paid more than others in his class. He must then be promoted to a higher class. If there is no vacancy in the higher class, the broad-minded chief will never stand in the way of his stepping into that higher class in another plant. If the assistant chooses to stay where he is for the sake of the training he is getting, that is another matter. Such things have happened and when they happen no higher compliment could possibly be paid to the chief.

Giving Help

The man in charge of a plant is, of course, responsible to his employer for the cost of power. It is his duty to produce power at the lowest possible cost. But this statement has its limitation. It is not his duty to go out in the night and steal coal. Neither is it his duty to hold by unfair methods an assistant who is worth more than the employer will pay. And it is an unfair method either to conceal the merits of such assistant from the chief of another plant, or to conceal that other chief from the view of his assistant. Even if it hurts us for the time being, we are all bound to help the younger man along.

It is economy of time and labor to discuss the work of the plant together with several men concerned at once. In most cases it is possible to find an hour, once a week, when the chief may meet with all or nearly all his men for a council. Here reports may be made on new materials and practices, special orders issued for the coming week, schedules arranged and rearranged, friction eliminated, questions and frank discussion invited. In the larger plants these councils will be held in several groups—the boiler room force in one group, perhaps, the oilers in another and so on. When time permits, there may be discussion of articles read in the technical periodicals, with criticisms. Attention may be called to the week's record in cost and economy and recommendations made for betterment.

Arousing Interest

This suggests another point, viz.; the interest which may be aroused on the part of a man who is given some insight into the performance records of the plant. This interest will be all the deeper if the individual concerned is allowed (within reasonable limits and with due verification), to keep his own record. As far as is practicable, the fireman, himself, should keep track of fuel consumption; if possible, of evaporation, also. The engine room assistant who takes the readings which determine the daily output curve will have a clearer knowledge of the load because of such clerical work. A service record, showing the duration of run of each piece of equipment, is one of the fundamental data of operation. This and other information may readily be kept in the form of a "log." The original entries may, if desired, be made on a slate kept on the engine room desk. Supplementing the service record, there will, of course, be the records of running conditions, with quantities and measurements needed for the determination and analysis of comparative economy. In advanced practice, as the engineer in training acquires experience and proves trustworthy, he may be allowed to share in the knowledge of some of the current costs. The prices paid for various supplies should interest him. He should be encouraged to record labor costs in such routine operations as boiler cleaning. Whenever debatable questions of policy arise, where a loss must be balanced against

a gain and the cheap way out discovered, he should be shown where such calculations are wrong, when they are wrong.

The statistical records of a well-managed plant may be subdivided about as follows:

1. The service record, or log. This is written up (and if desirable, classified, condensed and periodically summarized), from one or more sources of original data, obtained in the engine room, the boiler house and possibly elsewhere as well.

2. The data of operation, obtained by regular readings of gages, thermometers, etc., and to some extent, as well, from recording instruments and by reports of weights and quantities for brief intervals.

3. The summary of performance, in which the data of class 2 are used to express the economical results of operation, explanatory notes being drawn from the service record (1) as justified.

4. The cost statement, in which final results are expressed in money value.

Records in the last 3 classes are frequently kept as charts, in graphical form. The ability to plot such charts is not beyond what may reasonably be expected from a well-trained operating engineer. Some of the charts, not required for permanent records in the office, may, in fact, be prepared in the engine room with the aid of a soft lead pencil and a 2-ft. rule, answering every necessary purpose as well as if worked up in colored inks by a draftsman.

Training Derived from Tests

When simple tests are made to determine the merits of new devices, to establish the accuracy of instruments or to verify the current records of economical performances, the young engineer will have a special educational opportunity. He should be taught care in securing data, the probable errors in various sorts of readings and measurements, and the method of calculating results. The standard codes of the national engineering societies will have to be abridged, condensed and simplified for his use. They may well be. In a boiler test, for example, the 2 essential things are to weigh the coal and the water. All the rest of the code is in the direction of refinement and incident. If a man really gets these weights right—if he knows that every pound of coal weighed was burned, and every pound of water weighed was evaporated—he will be sure about 2 essential features of the test which often give the outside expert as much trouble as all of the refinements put together.

The writer recalls one experience in which a comparatively untrained operating man was taught how to calibrate a water meter. The fact having once dawned on him that meters are not accurate, the rest was easy. He grasped the facts that the error was about constant for a given rate of flow at a given time, and that it varied with the rate of flow and slowly with time and wear. Two or 3 tests were carefully made, the calculations explained, the importance of duplicating operating flow-rates driven home, and the training was complete, as far as this particular job went. This man took every opportunity thereafter of running a meter test. He was not quite as fond of working up the results, although he could do so. He was always curious as to the results, and was by all odds the best mechanical manipulator of the apparatus (which required some degree of quick, accurate control) in the entire plant.

Developing Deficiencies

In this case, the relative disinclination to compute results arose from deficient practice in arithmetical calculation, and this suggests the question of education outside the plant. The question has difficulties. Most boys who have spent 4 yr. in a high school look for some position which they regard as better than that of an engine-room attendant. At present, the bulk of our recruits come with only a grammar school training, or less. Again, they come, not directly from school, as they would then be under age, but usually after 1 to 3 yr. of rather purposeless and trifling work, during which they have usually forgotten much of such school training as might be useful. Even under the most favorable circumstances, nearly all of the men in the power-plant force start their vocational work with a school training entirely inadequate for their purposes. A good chief operating engineer must be a good computer and must have some knowledge of the principles on which the production of power is based. The engineer in training must, therefore, while acquiring experience and skill in the plant, devote some part of his time to a systematic study of the principles which underlie the work he is doing. Such a study should proceed in 2 ways. There should be an approach from the side of immediate interest, and another approach based on careful plans laid down by someone who knows what, in general, are the essentials of a plant worker's education. For example, if a new scheme of purifying boiler water is being tried, then is the time for the young man to dig into the chemistry of the subject, when it is a live and pressing matter. This is the approach from the side of immediate interest. On the other hand, he may find that approach partially blocked because of a lack of preliminary study. This is a difficulty often overcome by hard work, and when it is so overcome the grasp gained of the subject is sure; but as more and more such special subjects arise, time to attack them in detail from first principles will be lacking. The man is then apt to become discouraged and give up. This is avoided if, from the start, a careful plan of study has been followed, as slowly as may be necessary, but steadily and without intermission.

What should constitute such a plan of studies is a large question. Certainly most of ordinary arithmetic is necessary, but there are some unnecessary phases even of arithmetic, and perhaps skill and speed in computation are more important than the ability to analyze complicated or difficult problems. In algebra, the first essential is to be able to work with a formula, even if complicated, which ability implies familiarity with all the common signs of notation. The theory of logarithms is interesting, but the fluent use of the slide rule is a necessity. A step farther in algebra might give the ability to write an equation to express some fact or law and then to solve it. The fundamentals of physics (mechanics and heat), from some reliable text, and the simpler discussions of inorganic chemistry, with the principles of combustion, will round out the group of 4 essential subjects. Books on these subjects written particularly on power plant operation are mostly worth-

less, and the young engineer had better not buy them. He will obtain his balanced training better by applying to the daily work in his plant the fundamental principles of chemistry and physics gathered from his books.

The question of how to learn these things is now really no question at all, since evening schools or correspondence schools are available to everyone. Much can be done by some men when reading alone; but here the question of a book becomes of first importance, and the unadvised young operating engineer is quite apt to fix on inferior books. The instruction papers of the correspondence schools (at least those which the writer has examined) are admirable specimens of sound engineering and clear statement, often vastly superior—especially in the latter respect—to text-books used in colleges of engineering. They are safe guides. In the application of fundamental principles to plant problems, no book or books can possibly be of as much help to the studious plant man as one good engineering magazine. Such a journal, to be of real benefit, must be properly used; not glanced over for items of momentary interest and cast aside, but studied and preserved. Discussions should be weighed in the light of the reader's experience, and when special problems arise, the yearly index number should be examined for a comprehensive view of such problems in the papers of the past year. The engineer's working library should have as one of its most valued sections an unbroken collection of magazine back numbers. Several such collections are better still, and binding of such back numbers makes them most useful. The cost of binding is comparatively small.

In these general suggestions, nothing has been said of training in those business and moral qualities which must be acquired for real success in any vocation. We are here discussing only those special features of practical training which concern the operating engineer. But the engineer fills a place as man and citizen. His engineering training is but a part of that broader training which he must steadily acquire if he is to be useful and contented in his work.

Planning for Systematic Operation

CLASSIFYING ROUTINE WORK BY DEPARTMENTS; STUDY OF PLANT LOSSES AND FINDING THE STARTING POINT. CUTTING OUT WASTED LABOR AND LOST TIME. THE RIGHT TOOLS FOR THE WORK. THE INSTRUCTION CARD. STARTING EFFICIENCY OPERATION. BOILER ROOM ROUTINE. REWARDS FOR SUCCESSFUL EFFORT. BY ARTHUR L. RICE.

IN doing any work, the simplest method is usually the best. But it does not follow that the method that first comes to mind or that is in use, is the simplest. Unless careful thought and preparation are given before undertaking any work, there is sure to be loss from doing over, making mistakes and wasteful methods. Complete planning means "a program for orderly doing of a job before the job is touched, including tools and material to be used, how to go about the work, and the time needed to complete it. Problems are foreseen and met before they are encountered, so that delay and wasted effort are avoided."

In the power plant, it is to be assumed that the work is being carried on and that the planning becomes, therefore, a study of the work being accomplished with a view to determining the best way to do every job, routine or emergency, and if present methods are not the best to change them. There should be neither worship of precedents because they are or have been in use, nor eagerness for change, unless improvement can be definitely foreseen. Above all—go slow.

Logically, changes should start at the point where there is greatest loss, and this will frequently be found in the boiler room and with the method of firing and controlling the boilers. As this is a complex problem, however, and requires careful and extended testing, it may be better to start on some simpler task in order to gain experience.

It is assumed that the plant engineer has progressed far enough in his desire for efficient management to lay out a plan of organization and responsibility suited to his plant conditions and operating force and is ready for the next step. This will be the listing of the routine work of the plant, and all probable emergencies and the classification of the work among departments according to their responsibility. Divided responsibility should be avoided, and the lines clearly drawn.

Next comes the study of the men in each department, their fitness for different parts of the work and assigning of work accordingly. Here the experience and judgment of the heads of departments is of greatest assistance, and it is quite likely that the evolution of the plant will already have placed the men on work suited to them; but if a misfit is found, there should be no hesitation in making a change.

WHERE TO BEGIN

SO FAR has been a systematizing of present conditions, with such changes of responsibility among departments and men as is found necessary to give a consistent plan and suitable work. It is a rearrangement of working force to get best foundation for the creative work to follow. Then comes the laying out of a definite plan for survey of the plant and testing for waste of energy, material and labor.

	Power Consumed				Efficiency of each stage related to the preceding stage			
	No load on machines	Light load	Medium load	Heavy load	No load	Light	Medium	Heavy
Indicated H. P. of engine	30	60	100	150	70	83	90	93
Brake H. P. at belt pulley	21	50	90	140	90	96	98	98
H. P. delivered to generator	19	48	88	137	70	85	91	93
H. P. of current from generator	13	41	80	127	99	98	95	93
H. P. of current at motors	13	39	76	118	15	74	80	85
H. P. delivered to line shafts	2	29	61	100	0	90	95	96
H. P. delivered to countershafts	0	26	58	96				
Efficiency, referred to I. H. P.	0	43	58	65				

Two kinds of observations will be involved—one for efficiency of machines and equipment, such as making of steam by the boilers; the other, for efficiency of labor as in cleaning, repacking, filling oilers, etc. Both kinds may be started at once if men and time permit as, for instance, the boiler superintendent on the labor of clean-

ing boilers and the steam engineer and electrical superintendent on losses in generating units and transmission, starting from the indicated horsepower of the engine without load and determining by differences the load as machinery and shafting are thrown on. Then tabulate the efficiency from point to point as shown by the table herewith, taken from Industrial Engineering; afterward studying for the point of poorest efficiency and how to remedy the condition there. This is treated more at length elsewhere in this issue.

In the study of labor efficiency, the problem is more complex, because a man is more complex than a machine, and mind or the human element must be considered as well as matter.

Where the Time Goes

Observations should be made of time lost and needless labor due to use of wrong tools, bad arrangement of machines and control apparatus, thoughtlessness in methods of working, needless absence from duty and gossiping. The idea is not to strive for exhausting activity, but to make every motion tell and to plan definite rest periods, so spaced as to do the most good, thus making work easier and securing better results.

In many operations there is loss from lack of needed tools, work not ready when the men are, part of the men waiting for others, or needed supplies out of stock or not furnished on the job. The plumber who smokes cheerfully while his helper goes 2 miles to the shop for an 8-in. wrench, only to find on his return that another trip must be made for a 1-in. union, is a standard source of inspiration for the joke constructor, but similar, if not as excessive, delays may frequently be discovered when careful study is made of work in progress.

Conditions of light, heat, ventilation and cleanliness are important factors in securing good workmen; and in many plants, particularly in boiler and condenser rooms, the surroundings are not such as to induce loyalty and content of those who spend most of their working hours there. It is a long way from luxurious indolence, which some employers seem to fear will ensue if any attention is given to the comfort of the men, to a state of comfortable, alert activity which can be secured in the highest degree only by provision to maintain healthful surroundings. A well, strong body and a contented mind are requisite to secure response to suggestions for increasing efficiency of labor and corresponding rewards.

Proper Tools

Having remedied the ills mentioned, or put them on the way to remedy, the way is clear to begin the planning for most effective use of the facilities provided.

It should be made clear to the men that the object is not hurry and strenuosity, but to find the simplest and easiest way to do things, and that the final end sought is more work in less time and for higher pay. In the power plant the operations are not so brief that the stop-watch method used in machine shop operations is essential, although it may be found useful in some work, such as firing boilers, to determine best size of scoop, load for barrow, etc. But it is useful to know what length wrench handle is best for handling 1-in. nuts, considering breakage of bolts, time to take off and put on nuts, proper squeeze on packings and jarring loose of joints. For a given job, is an S or a straight handle quicker and more convenient? On a given joint which is broken somewhat frequently, does a sheet or molded gasket give quicker work and greater freedom from leakage? On such points the preference of men and general impressions are not to be trusted. There is one best way and one best outfit of tools and materials for each job, and it is the business of time-study to find that way, to record it, and then see that it is understood and used by those who do the work.

Before making final decision as to the proper operations, tools and the way operations are to follow each other, it is desirable to try the apparently best plan and study it for further improvement, but too much delay in deciding is liable to breed lack of confidence.

The time allowed should be determined by timing the operations of the job as subdivided on the instruction card or in even smaller subdivisions, then putting these part times together and allowing a reasonable margin for intervals between operations, the amount being best determined, for a while at any rate, by trial with the instructions on a practice job. After some experience in time setting, the allowance for rest and delays can be reduced to a percentage of useful time, which can be safely used on other jobs. In some cases it has been found to run at 30 per cent, but may be higher or lower.

Instruction Cards

When the final decision is made, the instructions should be written out in duplicate, using carbon paper to save time and insure an exact copy. One set is placed in the permanent "Organization Record Book" file, the other mounted on a card and varnished for use in the plant. These instructions should include the Time Allowed and complete detailed directions for tools and materials needed, operations to be performed and cautions, where necessary. The extra compensation allowed should be clearly stated, but may better be put on the work order than on the instruction card. In laying out work, the work orders for an entire day should be made out at the same time, when possible, and those for each man hung on a hook in the order to be followed, so that when one job is completed, the next is ready for him. Emergency work must be handled differently, but instructions should be ready, if the case is one that could have been foreseen. This is where the real test comes, and failure should be carefully foreguarded.

As an example of how an instruction card might be made up, the following is given, not for a particular job, but as typical:

Packing 6-In. Pump Piston. Time Allowed—I Hour

1. Enter time of starting. Read instructions carefully.
2. Get from stock:
   3 rings cut from ½-in. square spiral hydraulic packing on a 5-in. mandrel with diagonal ends and 1/16-in. clearance between ends.
   1 sheet packing gasket, 1/16 in. thick, 6 in. inside diameter, 9 in. outside diameter, 6 ⅝-in. holes on 7½-in. bolt circle.
   Can graphite mixture.
3. Get from tool storage:
   ⅝-in. hex. wrench with 6-in. straight handle.
   1-in. socket wrench.
   Hammer.
   Cold chisel.

Packing hook.
End scraper.
½-in. by 8-in. bolt.

4. Set piston at outer end of stroke and close steam valve tight.
5. With hex. wrench remove nuts from stud bolts and string on ½-in. bolt.
6. Remove cylinder head, clean flange surface and place under pump, inside up.
7. Remove old gasket and clean cylinder head flange, scraping if necessary.
8. With socket wrench, remove nut from piston rod and put on ½-in. bolt.
9. Remove follower and place on top of cylinder head.
10. Remove packing rings and inspect piston and rod end for cracks or flaws.
11. Coat piston with graphite mixture and insert new packing, breaking joints at thirds. Coat inside surface of follower and replace. Coat piston rod thread and replace nut. Screw up hard with socket wrench.
12. Coat cylinder flange with graphite. Place new gasket. Coat cylinder head flange and replace head. Coat studs and replace nuts finger tight.
13. With wrench, tighten nuts moderately, first one, then its opposite, until completed.
14. Open steam valve gradually and make sure that pump operates satisfactorily and that flange joint is tight.
15. Return tools and graphite to places in tool storage and stock.
16. Enter time of finishing, sign work order and turn in with this instruction card to boiler superintendent's desk.

Getting Results

This may sound unnecessarily detailed, but consider this job as being done by a man who has been in that plant but a short time, perhaps, in regular, orderly sequence, with no time wasted in finding what size wrenches, packing and gasket, are needed, nothing overlooked or forgotten. Then observe a similar job as frequently done in plants.

With the instructions ready, comes the problem of getting them into use. This requires tact, patience and perseverance. The one who is charged with this duty must keep in mind that he is first of all a teacher, whose work is to show the men how to follow the instructions and get the resulting reward. It is not a case of telling a man he must, but of showing him that he can.

After this man has succeeded in earning his extra reward, not once, but with reasonable regularity, another may be given instruction cards and taught to earn the reward, and so on. In no case should a man be paid less than his regular day wages while he is learning and trying.

When one department has been put on an efficient basis, it is time to take up another, but not until then. Working at more than one point at a time will result in confusion, too little attention given to the men who are learning the new ways, with resulting discouragement. And the work should not be hurried, either in preparation or adoption, so far as the instruction card and special-reward features are concerned. The sooner improvements in tools, arrangement of plant and working conditions are introduced the better, for these will be of benefit under any system of assigning work and paying wages.

The writer believes that the instruction card and special-reward method is of great value in any plant, large or small, but realizes that its advantages in the large plant will be more evident than where but a small force is employed. In any case the permanent "Organization Record Book" is essential to continuous operation, but should not be, like the laws of the Medes and Persians, unchangeable. Standards ought to be simply a record of the best knowledge up to the present, and should be revised—upward—as new knowledge is gained.

Again, standards are of no effect if they are not attained. Here lies the difference between standards and ideals. Ideals are the best we can conceive of; standards are the best we can reach under present conditions, definitely stated, so that performance may be compared with them.

Having determined our standards, an inspection system is necessary to see that they are lived up to, and this system naturally becomes the duty of those in charge of departments. Useless details should be eliminated, the forms used as few as will get the desired results, and the system regarded always only as a means to attain the standard of performance.

Somebody says: "That's all red tape." Yes, it is. So is a pay envelope, but you like its looks, nevertheless. And when an emergency arises, or there is a sudden vacancy in the organization, you, who are responsible for keeping things going, will be thankful for the system and instruction card which tells whoever is to do the work, what to do first, and, next, and next—on to the end. The best chief engineer or plant manager is the one who meets emergencies best,—whether he is on hand or not.

Better Pay in the Boiler Room

Besides increase of labor efficiency, there is the matter of efficiency of apparatus, which is, in turn, considerably dependent on efficient handling. Questions of design and operation are treated in other articles, but it is worth while to study briefly the possibilities in what is now recognized as the most important part of the plant, the boiler room. At the recent meeting of the A. S. M. E. the opinion was advanced by many plant managers that the highest paid labor in a plant should be that on the boilers, and that a "combustion engineer" might well be employed, for, while reduction of waste can be made in operation of engines, generators and motors, it is in the furnace and boiler that big wastes can enter unnoticed, unless conditions required for economy are determined and maintained.

To secure efficiency in this department requires the same course of observation to discover useless labor, as in other places, tests for points where wastes are occurring and removal of the causes of such wastes. Air leaks through setting, short circuit of gases through broken baffles, restriction of gas passages, steam and water leaks are to be eliminated and then kept out, as told in detail in other articles. In addition, best methods of firing must be determined for the given plant, and a system adopted which shall insure its constant use. Besides the definite instructions and reward for reaching standard results, the contest and love of a game may be introduced effectively by posting records of coal burned and efficiency of operation of each man or watch.

Points to be considered are: Position of coal supply with respect to fire doors; size of barrow or car; size of scoop; frequency of firing and amount each time; position of control valves and instruments; accessibility for cleaning; best treatment of feed-water; securing of high-

est feed temperature; flexibility of draft control by damper; ratio of grate area to fuel.

Then, by trial and analysis should be found the best possible result that the plan can give, and the conditions of thickness of fire, water level and draft that result in nearest approach to that result. With a given fuel, for every load on a boiler there is a definite thickness of fuel bed that gives best efficiency and a definite draft in the fire box that gives best rate of air supply. As load changes, thickness of fuel bed and air supply should change, not with momentary fluctuations, but with periodic rise and fall of load line. These relations should be determined and tabulated or charted.

In doing this it is necessary to *know* coal used and its heat value, feed-water supplied or steam used, temperature of feed, composition and temperature of stack gases, draft conditions in fire box and stack, combustible in ashes; and means must be found to keep track of these values. The cost need not be great, however, for ingenuity will get results, even from crude methods. With the desired conditions known, the fuel bed is kept in reverse wedge form at thickness called for by the load, as shown by water meter, steam-flow meter or wattmeter, care being taken that cracks and holes in the fire are not permitted, and firing being by the alternate method, in small amounts and frequently. Thickness may conveniently be gaged by marks on fire door or frame. By use of the damper (not ash pit doors) the draft over the fire is held at that value known to be best for the thickness of fuel bed. This gives the required conditions for best efficiency of furnace.

The indications of the CO_2 recorder and the condition of the flame in the combustion chamber will tell whether proper attention is given the fires or not. A differential draft gage should be used, as the draft over the fire is often not over 0.3 in. and the U form is not sufficiently accurate. Draft in the stack is not useful as a guide to fire-box conditions.

Check Records

It is desirable, however, to keep running checks to make certain that the firing is properly done and that feed-water heaters and boiler heating surfaces are up to standard. Record should be made of coal used by each fireman and the ashes produced by him; of gas temperature as it leaves the heating surfaces of the boiler; of carbon dioxide content at the same point; of feed-water temperature and amount supplied, and of boiler pressure.

Coal used will be found from the coal passers records or the hopperfuls to the mechanical stokers. The heating value of coal from tests with a bomb calorimeter; this value will be practically constant, so long as coal comes from the same mine or vein and shows the same percentage of ash. Water supplied is shown by water meters or flow meters, but if by the latter, records must be made for each boiler or for supply to main engines, auxiliaries and live steam to heating system. Steam pressure is from a recording gage and temperatures of feed, superheat and gases from recording thermometers.

From these the efficiency of a man's work can be determined and his record posted, but some engineers advocate the posting of record and paying of reward for average watch performance, rather than individual, in order to secure team spirit and work and avoid temptation for one man to try to improve his own record at the expense of a fellow fireman in his watch.

Basis for Reward

On this point there has been much argument and difference in practice. Some form of bonus or premium is used, but whether this shall be paid as a fixed amount for accomplishing a definite task, or a varying amount according to the success attained and what shall be the factor determining whether and how much reward shall be given, are disputed points which each chief engineer must settle for himself. For labor efficiency, Gantt advocates a bonus of 20 to 30 per cent of the day-wage rate, if the work is done in the time allowed, no reward being given unless that time is reached and no extra reward for cutting down the time. Others have used a maximum time allowed, for which a small extra premium, say, 5 per cent, is given and the premium increased as the time taken for the job decreases. The former method tends to eliminate all but men with high capacity, give them a high rate of pay and no incentive to overwork; the latter gives every man a chance to increase his income, but offers temptation to excessive effort. This can, however, be guarded against by setting a maximum premium at a point which will not call for excessive effort and will reward extra effort to attain the desired standard, even though the effort be not at first successful.

Just what scale of premium should be adopted must depend on the work. As a possible suggestion, in the case of packing the pump piston already given, if the previous time taken was 2 hr. and the time allowed 1 hr., a scale might be, for 1¾ hr., 3 per cent added to day-wage rate; for 1½ hr., 8 per cent; for 1¼ hr., 15 per cent; for 1 hr., 25 per cent; for less than 1 hr., no extra above the 25 per cent.

For apparatus operation efficiency, the basis is usually percentage of machine efficiency reached. Polakov has based reward, in one instance, on reaching 70 per cent, combined furnace and boiler efficiency, this standard being based on a study of plant possibilities, where the former efficiency was 67.9 per cent, and that under best test conditions 76 per cent at 90 per cent rating, and 77.7 per cent at 115.5 per cent rating. Reward for maintaining 70 per cent was made 25 per cent added to the day-wages rate.

Other methods of payment have been based on percentage of CO_2, coal used, or water evaporated; no one of these is a measure of boiler efficiency, however, and each is liable to "doctoring" by firemen more anxious to earn extra pay than to aid in improving plant performance.

Another method proposed is based on maintaining a constant difference of draft pressure between furnace and stack, as shown by recording draft gages, and seems to have advantages in simplicity and freedom from tinkering, but no data are at hand as to how it has worked in practice.

Any plan should give reward for high efficiency in coal burning, or utilizing energy, as on that depends the cost of plant operation; and should be an equitable division of saving between the owner, who supplies conditions permitting of making the saving, and the operator, who supplies the attention and interest to get results from the improved conditions.

Inspection and investigation must be provided to make certain that proper conditions are maintained and that operating men keep up their effort. An instance is the system at Warrior Ridge, Pa., plant, where W. N. Polakov has secured noteworthy results. Investigation is made of every case where the fireman fails to earn his bonus by keeping up efficiency, and the reason reported. This gives a chance to place the responsibility on failure to keep the apparatus up to the mark or lack of skill of the fireman or just plain indifference; in any case, a remedy can be found.

Outside Supervision in the Plant

WHERE AND WHEN OUTSIDE SUPERVISION IS ADVISABLE, REQUIREMENTS OF POWER PLANT OWNERS AND CLASS OF ENGINEERS BEST QUALIFIED FOR THE SERVICE. BY HUBERT E. COLLINS*

THIS subject has been before engineers for several years now, and the owners, operating and consulting engineers have had opportunity to discuss it thoroughly, as well as note the results of its practical application.

Outside supervision, or the general direction of the plant by an engineer other than the operating chief, has existed to some extent in many localities for many years, or since power plants first existed. Who among us cannot call to mind many times in our experience where the owner has kept in touch with builders of engines, boilers, or with other manufacturers to get the advice needed at times to operate the plant better; This was outside supervision, and always resulted in good to both engineer and owner.

Then came the companies of supervising engineers, later called efficiency engineers. About 10 yr. ago, the head of the best-known supervising engineering company in the East started in a small way and has built up a splendid business, of benefit to all concerned. Through this man, more than any other, the question of outside supervision has been discussed and through its application results noted.

OUTSIDE SUPERVISION PERMANENT

BOTH SIDES have learned from the experience and, after watching results, it is certain that outside supervision has come to stay, and although it does not apply to every case, there is a large field for it. It is also certain that where these methods are of service, they can be applied with benefit to all.

In order to obtain the best results, it is necessary for all parties concerned to recognize their own and the other fellow's limitations and organize a working unit. On the one hand, the supervising engineer must admit that the operating engineer knows his plant in detail more intimately than others can. He knows the individuality of his machines better and can best tell the results of application of oils, packings, etc., and knows many things one cannot learn in any other way than to be with them continually. The operating engineer must feel that the consulting engineer can bring a training due to association with business men that is denied the man in the engine room, and can bring to bear a wide range of knowledge of general practice. The consulting engineer is called upon to consider problems so varied that each one is a special study and cannot help but give him a general knowledge at least of more phases of engineering than can be gained in the engine room alone.

For one to disregard the knowledge of the other is foolish. For each to recognize that the other can bring special knowledge into a working combination for the common employer means good for all.

QUALIFICATIONS OF OPERATING ENGINEERS

IN ALMOST every section of our country we have some splendid examples of operating engineers. Men who are mechanics, have had a wide practical experience, who are gentlemen and have the confidence of their employers to such an extent that they are allowed to act as consulting engineers for other firms as well—these can pretty well care for their own plants. But among the majority of operating engineers, a working combination of operating and consulting engineer can prove beneficial. The man who has had experience in one plant alone dreads to change to a different type of plant. Not so many years ago, engineers were divided largely into 2 classes, Corliss and high speed, and when a man was called from a Corliss engine room to one of opposite type, or vice versa, he did not like it until he became used to the new type and learned that the principles were the same. Then came condensing engines, internal combustion and turbines. The power-house man who was used to the largest units known, moonlight schedules and franchise requirements held his head high until he entered a 250-hp. office building plant, found there were such things as electric and hydraulic elevators of many varieties, never knew how to tell the difference between alternating and direct-current motors when he heard them, and was lost in a maze of cold and hot-water systems, fire service, etc., that to the owner at least are more important than the generating plant itself. The older men who have gone through all the changes of 20 yr. or more can tell how busy it has kept them to be informed of changes, and how many times they thought they were up against it when they were called upon to change to a plant where they must learn all the valves and apparatus in addition to an entirely new type of prime mover or new systems.

*Mr. Collins' work began with 10 yr. as mechanic, erecting and operating engineer, having charge of plants during that time as high as 20,000 hp. This was followed by 9 yr. in contracting, consulting, supervising and expert work, being in charge of as many as 28 plants at one time. Among those served as consulting engineer were Sulzer's Harlem River Park, Brighton Beach Casino, Knickerbocker Chocolate Works, Malcolm Brewing Co., Hotel Knickerbocker, N. Y. & North Shore Ry., Saks & Co., J. G. White & Co., Ltd., London on the Para, (Brazil) Electric Railways & Lighting Co., and Tri-State Electric Railways of Ohio.

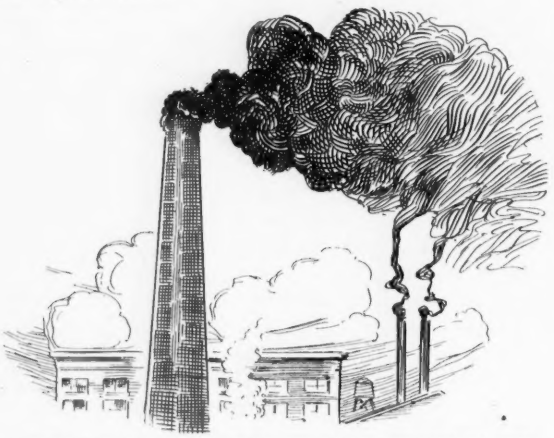
It simply emphasizes the fact that the man with the greatest general knowledge is fitted to help the man in the narrower school of experience. We also know that the greatest attention is now given to the boiler room, whereas a few years ago it was a secondary consideration; but the same experiences apply here in a general way.

Experience has shown that by no means is outside supervision necessary in every plant, any more than low-grade fuel can be burned under every boiler in the land, because it is a success in some. "Conditions alter cases," is an old saying, truly applied here to both assertions.

Outside supervision depends fundamentally on 3 factors—the requirements of the owners, and the amount of knowledge possessed by the operating and consulting engineers to fulfil them. Then let us consider them in order.

REQUIREMENTS OF THE OWNERS

A MAN TO operate the plant.
2. Keep it in repair.
3. Direct the engineering force.
4. Keep records and make reports of the details of power production.



A STEAM PLANT FLAUNTING ITS INEFFICIENCY TO THE WORLD

5. Study and apply methods of economy in operation.
6. Direct purchase of best apparatus for economical operation and upkeep.
7. Direct purchase of best supplies consistent with right prices.
8. Design new additions and alterations.
9. Design new plants to suit requirements.
10. Make appraisals of apparatus.
11. Advise on liability insurance, fire insurance and prevention, law suits, etc.
12. Study apparatus or equipment, not strictly of the power plant, but which can best be attended to by the engineering force.

The operating engineer can best fill the No. 1 requirement, and the manner of his so doing determines his own status and that of his fellow engineers with his employers. To be a simple starter and stopper will not do, but every move made must be studied and understood. It is certain that either college or practical training is of little benefit unless it develops a thinker and it can be shown in plant operation as well as anywhere else, how much the operator has developed in this direction.

We look to the operating engineer in charge to fulfil the second requirement, also. But in the event of the consulting engineer having had a machine-shop training of the old school, he may know more ways out of a difficult situation than the younger operating man who has had no machine-shop experience, or at best is a one-machine man. This does not imply that all young operators lack mechanical training, but the number of those who possess knowledge born of a machine-shop training, from bolt cutter to erecting work and embracing all classes of machine-shop work in the process, are certainly growing less. For this reason, the man who best fills this requirement may be one or the other.

The third requirement is really hard to fill; but, all things considered, the operating engineer is the most likely one. It requires an intimate knowledge of the men and ability to see things as they do and get their viewpoint. A practical knowledge of their duties is also essential, for a workman will listen to instructions of an intimate nature regarding his duties more closely if you can demonstrate to him personally. But it also requires more than this so to instruct him that he can follow you, instead of letting you do it for him. Many skilled workmen who can lead all the rest make poor foremen, because they do the work while the rest look on. All things, considered, however, the operating engineer more often fulfils this requirement.

In the matter of records, the operating engineer is, by environment, better fitted to report the essential data referring to production costs, output, etc. This has been a comparatively recent development in the duties of this position and to fill it is within the reach of every intelligent engineer. The consulting engineer can bring to bear a knowledge of practice in many plants and a variety of industries, but in applying it to a special plant he needs the co-operation of the engineer in charge.

In the sixth requirement the operator often falls short, because he is slow to try new methods or may be apt to feel that because a new supply or fuel is cheap it is no good. This is more often shown in city plants where a lower grade fuel is proposed than that in use. Many engineers and firemen are against the use of a fuel cheaper than they are using, because it is cheaper and may make more work. They reason that a cheaper fuel will not keep up pressure, but do not know for certain. A test is the only way to decide. The consulting engineer generally has had experience with numerous fuels and types of plants where fuels of certain grades are best suited. So, if the engineer in charge has not tried more than one fuel, the consulting engineer can best supervise the adaptation of a new fuel to the needs of a plant.

The seventh requirement, as in others, calls for co-operation on the part of the operating and supervising engineer; for while the one can get better prices by purchasing for several plants, yet we know it remains for the man on the job to make the supplies work to best advantage.

Requirements 8 and 9 are generally better filled by the consulting, supervising engineer. On honest inspection, how many operating engineers are prepared to figure capacities, strains, stresses, etc., of all apparatus, and are so free from bias that they can decide on merit alone instead of familiarity with a certain design?

The tenth and eleventh requirements, as a whole, are, in the majority of cases, best filled by the consulting, supervising engineer.

The twelfth can best be filled by the operating man, if he is willing to take up duties not strictly covered by his training as an engineer. If he thinks they are outside his duties and insists on adhering to the latter alone, then the office force of the consulting engineer can best supply the need.

These requirements here enumerated do not cover all the ground, but do cover essentials. On careful consideration, it can be seen that supervision is not needed in every plant, but can be of service in many. It will not be a success anywhere, if there is not co-operation. To get co-operation requires men big in mental make-up, ready to be just and each learn of the other.

Procedure for Owners

Where the owner feels that he lacks some of the requirements of a complete engineering organization, he should consider each phase in a manner as herein. If he needs strictly engineering service, as in cases where the plant is operating poorly as to capacity or economy, he should pay for a thorough examination and report on the condition of his plant with recommendations for improvement. He should pay for this report. Then he should consult with the supervising and operating engineer as to subsequent procedure to get results and assure himself that he will get the co-operation necessary for success.

If the supervising engineer is sure of himself, he should take the supervision on a percentage-of-saving basis. This will range from 10 per cent to 50 per cent of the savings according to the size of the plant. In other instances the outside engineer can offer to operate the plant on a fixed cost per year, taking whatever saving he makes for himself. This is in the event that the owner has had such erratic expenditures from year to year that he is glad to have the assurance of a fixed sum, or the charge fixed by the outside man is enough less than previous years to make the offer attractive.

In other instances, the owner pays a fixed charge per month for supervision. This ranges from $20 a month, the simplest plant, to $100 a month, for office buildings, up to 12-story, having their own plant. Above that, special charge must be made.

The ethics of supervision can be met if the operating engineer is big enough to welcome co-operation and if the supervisor does not try to take away the individuality of the operator and is willing to give him just credit.

Sizing Up a Steam Plant

Some of the Features of a Plant Will Note and the Impressions He Which an Observing Visiting Engineer Will Form. By Osborn Monnett*

Knowledge is necessary for increased efficiency, whether obtained from schools, books, or practical experience, and an engineer, if he wishes to keep abreast of the times, should never miss a chance to add to his store of this useful commodity.

One of the most neglected and at the same time most valuable methods of increasing an engineer's fund of information, is in visiting neighboring power plants from time to time as opportunity offers. In this way he gets out of the narrow routine of his own plant and familiarizes himself with conditions and methods which are new to him and which have a great educational value. In visiting a plant, a time should be selected if possible, when the plant is not on parade, but is carrying its regular load in the ordinary manner.

Location of Plant an Important Factor

When approaching the steam plant, it is well to pay particular attention to the location of the plant with regard to the coal supply, whether by railroad or by wagon; also note whether the coal bin is located so that the coal will feed to the boiler room floor with a minimum of labor, or is so located that an extra handling will be required in the boiler room. It must be remembered that the points you observe in a neighboring power plant

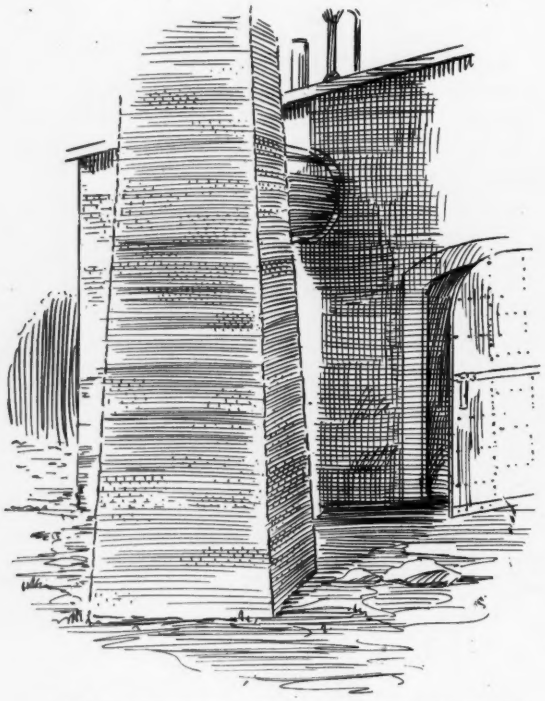
THIS ON A COLD DAY INDICATES THAT SOMETHING IS WRONG

*Practical experience in steam engineering began for Mr. Monnett as oiler on the Great Lakes, where 4 yr. was spent with the Wilson Transit Co., of Cleveland. He then came ashore in Ohio, and shortly went to Silvis, Ill., as chief engineer of the railroad repair-shop power house of the Rock Island System, making a special study during his 4 yr. there, of the chemistry of combustion and industrial processes. In 1907 he joined the editorial staff of The Engineer and later became western editor of the combination of that paper with its eastern contemporary. In 1911 he was appointed Chief Smoke Inspector of the city of Chicago, which position he still holds, passing on all boiler plants installed in the city and all reconstruction work on boiler settings, and being in close touch with operative details of over 15,000 steam plants.

are just as valuable to you when the methods are faulty as when they are correct, provided you are wise enough to draw a lesson therefrom. Extra wages spent in moving coal are a direct charge on the over-all efficiency of the plant. The manager looks at the dollars and cents rather than the efficiency of any particular apparatus, so that while the boilers may be working at an efficiency as high as 75 per cent, and the saving thereby is offset by the wages of an extra coal passer, then the result to the owner is no better than if the efficiency of his boiler were much lower.

Exhaust Head and Stack Have Their Tale to Tell

Before going into the plant, note whether the stack is smoking, as this has come to be taken as a mark of inefficiency; also note the exhaust heads with special



A STACK WITHOUT A CLEAN-CUT DOOR MAKES FOR INEFFICIENCY

reference to the time of year and the weather. If it is winter time and exhaust steam is blowing liberally into the atmosphere, it may be possible that there is a waste taking place and that live steam is being used in the heating system to make up this waste. At any rate, you can make a mental note of this and if such proves to be the case, you can resolve not to make the same mistake in your own plant.

In entering the plant it is well to drop into the boiler room first, as this is where most of the money is spent in the shape of fuel and where ordinarily the most costly mistakes are made. On arriving in the boiler room a general survey of the conditions should be made without disturbing the work of the fireman. You should note the facility for working the fires. If it is a hand-fired plant, have they shaking grates? If a stoker plant, is the coal fed by gravity, and what are the facilities for taking away the ashes? The points to be noted are the minimizing of labor in the boiler room and increasing the comfort of the employes, which is a matter of greater importance than the average engineer appreciates.

Liberal Air Supply is Necessary to Efficiency

One of the vital things to be noticed in sizing up the probable efficiency of the plant, is the matter of air supply to the boiler room. Notice whether there are an adequate number of windows or ventilation ducts to supply air for the furnaces, remembering that for each pound of coal burned there must be about 24 cu. ft. of air at ordinary temperature admitted.

If these ducts or windows are inadequate in number or tightly closed, as is often the case in winter, the efficiency of the plant is being badly handicapped, and the capacity impaired. Frequently it will be found that boiler rooms operate under a vacuum as high as 0.45 in. of water. Under this condition it is easy to imagine the drop in capacity which will result. If the capacity drops, the owner is not getting a proper return for his money, and the over-all efficiency is lowered.

Hot Boiler Fronts are a Bad Sign

Stroll down in front of the boilers, and, especially if they are of the horizontal return-tubular type, hand fired, note the amount of heat radiated from the boiler fronts. A little observation on this point will show that there is a big difference in plants in regard to this matter. Of course, there always must be a normal amount of radiation from any hand-fired boiler setting. A little practice will determine about what this should be. Anything more than normal radiation is an indication that the boiler plant is in distress. This distress may be in a restriction over the bridge wall or a combustion chamber full of soot, or an inadequate area under the skeleton arch, dirty flues, an improperly designed damper, or a breeching full of soot. Again, the stack may be filled with soot up to the intake of the breeching. Any of these causes will cut down the free passage of the gases away from the boiler and will indicate a "bottled heat" condition which is a distinct detriment to the operation of the boiler plant and a serious obstacle when trying to attain efficiency.

If the radiation is excessive, note the temperature of the flue caps. If they seem to be sizzling hot so that the paint is being burned off, the trouble will be between the boiler and the stack. Maybe the damper is twisted on its stem and although indicating to the observer that it is wide open, is in reality partly shut. This is a condition surprisingly prevalent.

If, however, the flue caps seem to be at a normal temperature and the radiation is from the fire doors, then the trouble will be indicated in the furnace setting itself. It is astonishing how a little practice in sizing up a boiler plant in this way will be sufficient in many cases to indicate a serious defect in the physical condition of the plant and enable the observer to point at once to the defect.

Leaks Cost Money

Before leaving the boiler fronts, examine the flue-cap doors to see if they are tight or leaking badly. If they leak, capacity is being sacrificed and it might even be possible that one less boiler could carry the load. What this would mean in plant efficiency is plainly evident.

Free Gas Passes Absolutely Essential

Too much stress cannot be laid on the importance of keeping the gas passes clean. Hundreds of plants are struggling along trying to carry their load with wagon loads of soot in the horizontal runs of breeching and with the base of the stack full of soot. Pay particular attention to the condition of the clean-out doors in the settings, as an indication as to whether or not the plant is efficiently managed. Sometimes these doors are not opened often enough to keep them from rusting shut, and when this condition is found, you may be sure that the combustion chamber is full of dirt and an inefficient condition exists.

LEAKY FLUE CAP DOORS MEAN WASTE OF FUEL

It is scarcely believable that engineers will neglect these things as much as they do. The author has found clean-out doors that had to be opened with a hammer and chisel. In speaking of clean-out doors it would be well to make a mental note of the desirability of having them work on hinges, rather than rest on lugs as they sometimes do. A door that works on hinges can be easily opened for an inspection of the combustion chamber and frequent use should be made of this facility by the engineer who hopes to keep his plant up to the highest point of efficiency.

The visiting engineer should make a point of informing himself at the earliest possible moment as to the condition of his own breeching and stack. Instances have been known where partly closed, forgotten dampers, have existed in breechings without any indication from the outside that such was the fact. The lining of the breeching may be in wretched condition and interpose a restriction in the gas passes without the slightest indication from the boiler room floor. For this reason it is not too much to require that somebody actually crawl through the breeching from the boilers to the stack at least once a year, to know positively just what the condition is.

Another thing to be noted is the condition of the boiler brick work. If there are cracks and apertures in the brick work out of which a little line of soot is distributed over the face of the brick, it indicates that there is serious air leakage and that the furnace is not operating efficiently. Also, note whether or not the top of the boilers are covered and whether the steam piping in the boiler room is well lagged. If not, there is excessive radiation at these points which has a distinct bearing on the efficiency of the plant as a whole.

While in the boiler room, also note the location of the feed-water heater and whether or not there is a thermometer in the feed line. If not, the chief engineer of the plant is overlooking an important matter bearing on efficiency. The feed-water should of course be kept at as high a temperature as possible, but if he has no means of knowing what the temperature is, it is easy to understand how he can let his efficiency drop off.

Note whether or not the steam piping is properly drained and if so, whether the discharge of the traps goes to the heater or to the sewer. Such condensation makes good feed-water and saves a great deal of heat if properly used.

Testing Facilities Make for Efficiency

Many boiler rooms are equipped for making evaporative tests with scales, tanks, etc. It might be a good thing to note whether the plant in question is so equipped or whether there is floor space and piping connections making this a possibility. If so it can be taken to indicate that an attempt is being made to keep the plant up to its highest efficiency.

In the Engine Room

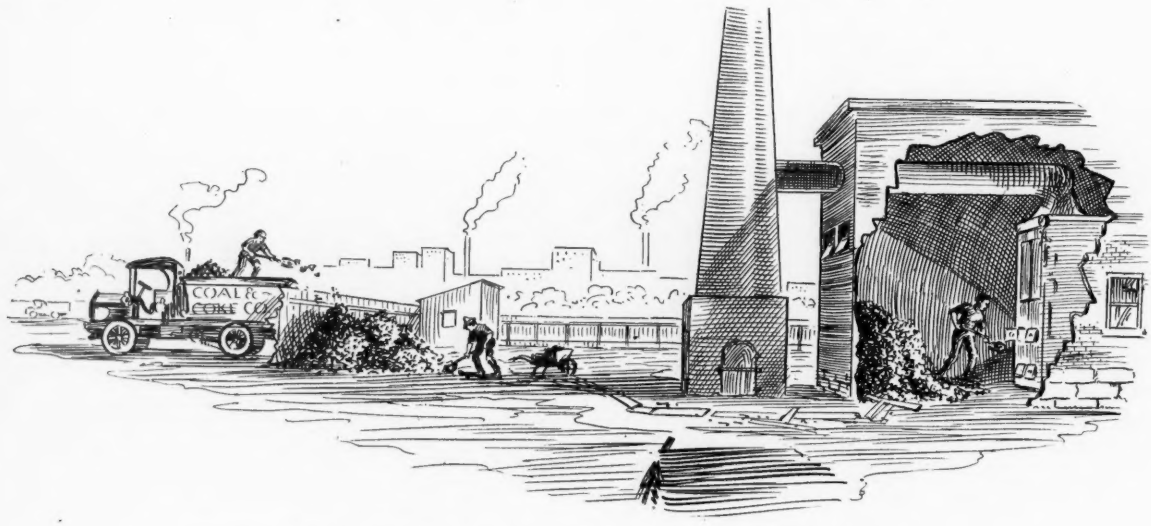
In passing to the engine room, a general orderly appearance will indicate efficiency. It is, of course, impossible to determine from inspection just what the steam consumption of the engines may be, but if the indicator piping seems to be used and not merely an ornament to the cylinder, it will give you an indication as to whether the engineer is alive to the possibilities in this direction. Many indicator rigs wear themselves out as ornaments and the indicator piping is frequently plugged and painted over so that a glance will determine that it has not been used in years. This is a bad condition and shows that the engineer is not up to the minute in this regard. Again, if the engine is knocking badly and loose on the foundations, it may be taken as a certainty that it is not as efficient as a quietly running and well anchored engine. This may or may not be due to the neglect of the engineer. If the condition is chronic, however, it is to be charged more strongly to the engineer than any other cause. While he cannot change the character of the foundation, he can in most cases key up the engine to run reasonably quiet and if he fails to do so, it merely indicates a lack of interest in his work which is bound to show on the efficiency record.

Condition of Auxiliaries—Good Indication

Some idea of the true state of affairs can be obtained by noting the auxiliary machinery. If the steam packing of the stuffing boxes leaks and there is a general run down condition observable, it may be taken as an unfavorable indication. Note the engine room walls and see what facilities the engineer has in the way of recording instruments. There should be at least a recording steam gage and a recording draft gage. The recording steam gage checks the operation of the boiler room at night and at times when the chief engineer is not present. The draft gage is also a good check on boiler room operation and should be studied daily by the man in charge.

Frequently oil which has been used a number of times in the oiling system can be used to advantage on some of the slower moving auxiliary machinery. If your examination shows that this is being done, it brings out another effort of the engineer to keep his plant up to the highest efficiency.

While in the engine room it is well to notice whether there is a system of record keeping in use. See whether the draft over the fire is known, also the rate of combustion per square foot of grate surface, analysis of the coal, etc. If these and similar items are known the chances are that there is being made an attempt at least to keep the plant tuned up to a fair pitch of efficiency. Unquestionably, the information to be obtained by



TOO MANY STAGES IN THE COAL-HANDLING SYSTEM EAT UP THE PROFITS

Note the method of oiling the engines, whether automatic or by oil cups. Also note whether or not the lubricating oil is collected and filtered to be used over again or whether it is run to the sewer and wasted. This is an item which will run into money in a year's time.

casual conversation with the operatives in the plant, together with what can be picked up by careful observation, will draw the attention of the visitor to many points which he can apply or avoid in his own practice, as the case may be.

Introducing Efficiency Methods

Studying for the Best Place to Begin; Secure Co-operation of the Men, and Best Use of Present Equipment; Set a Standard and Train to Reach It. Be Conservative About Expensive New Equipment. By Lucien I. Yeomans*

Since "scientific management" has been defined as "the best use of the present means," and "efficiency" is conceded to be "a result or condition to be desired," it is at once evident that, inasmuch as there is nothing new or startling about it, the proper methods of application to follow are those which have been most often proven successful in the past introduction of betterments in operation or management.

It has been variously argued, by those most prominent in the extension of this work, that this or the other way is the only proper way to attack the problem.

There is no one way to do it. In connection with machine shop practice, I have tried all ways proposed from a simultaneous attack at all points of weakness, coincidently, to an inconspicuous effort directed at one small section of one small department.

If the owners of a business have nerve and confidence in the movement, it may be better to follow the first method and shock the organization into the spirit of the thing. If there are influential skeptics at the head of affairs and criticism of unfinished work, which chil-

*Starting as an apprentice with Brown & Sharpe Mfg. Co., of Providence, Mr. Yeomans worked for several years as machinist and toolmaker, then as pattern maker and toolroom foreman and afterward as designer. His advance led him to the superintendency of the Goodell Co., Antrim, N. H., Heald Machine Co., Worcester, Mass., Fuller & Johnson Mfg. Co., Madison, Wis., the Link Belt Machinery Co. of Chicago, Superintendent of Motive Power for Armour & Co., General Superintendent of Factories for Sears, Roebuck & Co., and finally into consulting practice on efficient management and operation of plants and works, in which he has been engaged for the last 2 yr.

dren and fools are proverbially supposed to be excellent judges of, is to be expected, it may be better to follow the other extreme and make as little splash in breaking the ice as possible. From whatever angle the problem is approached it must always be remembered that there is nothing new about it and that the attempted movement consists only of intensified betterments—many in a short time—instead of duly considered routine improvements, adopted at intervals and expected by everyone as a matter of course and natural evolution.

Procedure for Power Plants

Undoubtedly it would be better to be conservative in the proposal of such practice to a large manufacturing organization composed of many foremen and it is doubtful if the best results would ever be secured in the least time by calling all department heads into consultation and taking them entirely into confidence by outlining the radical betterments about to be attempted. Too much opportunity is in that way afforded for ill-informed discussion and the keen edge of latent curiosity is dulled. Conditions in power-plant operation are somewhat different and the lesser number of employes and fewer division heads render the task more simple. If I were required to undertake the operation of a large power plant again, I should outline my procedure from an efficiency standpoint promptly and not make any statement to any person, either over or under me in authority, as to my intentions or contemplated efforts.

The installation of betterments, in both equipment and method of operation, would seem to be nothing radical or unusual or other than might be expected from a new man with a record to establish.

The most successful surgeons of our day always, as a preliminary to operation, take especial pains to work their patients into such a frame of mind as will best second their skill and the last thing impressed upon a patient's mind before going under the anaesthetic is that the operation required is simple, that there are no cases on record where a patient ever died from it, that there is no occasion at all to worry about it; in fact, that it is something to be regretted as an annoying circumstance, but nothing else. Just so would I attack the situation in my power plant, and no one would ever get any impression from me that anything unusual was about to happen or that anything designated by a long word not usually heard around such a plant was to be attempted.

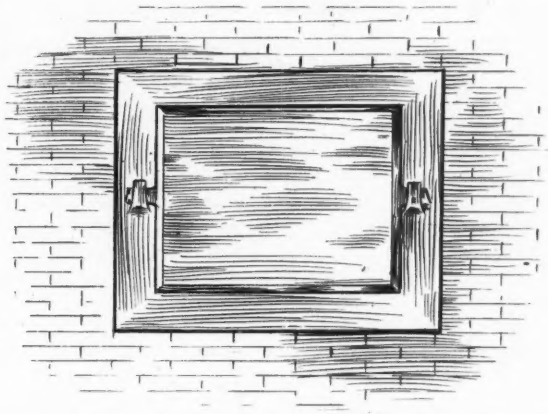
I should first ignore the possibility of betterment through improved equipment and I should devote my entire time to a study and development of the best practice in the existing plant without changes. The personnel of the entire organization should then be studied and quietly brought up to standards that would exist in my mind, as they do in the mind of every chief engineer.

The necessity for this is obvious—most property owners who have a power plant regard it as an expense department. They class it with their legal department and other necessary evils. It is particularly annoying to them to contemplate substantial expenditures in connection with any expense department, although they will readily consent to greater capital outlay on a manufacturing department that would show but a fraction of the return upon the investment; so it is really necessary to develop a high efficiency in the existing plant and establish such records of performance as will supplement later recommendations for improved equipment.

Handling the Man Higher Up

One thing must never be lost sight of. It is always easier to handle the man under you than the man over you and a man entrusted with the management of large affairs, though he be endowed with great ability and a vast knowledge of his business, will never be highly efficient nor able, in a broad way, to promote efficiency in his department, unless he also be able to give and take and sacrifice, when necessary, for the ultimate success of the work. The best man in the world could command about $5 a day for his personal services and he is more valuable just in the same proportion he is able to secure results from others and co-operation and harmony in any organization he is a member of.

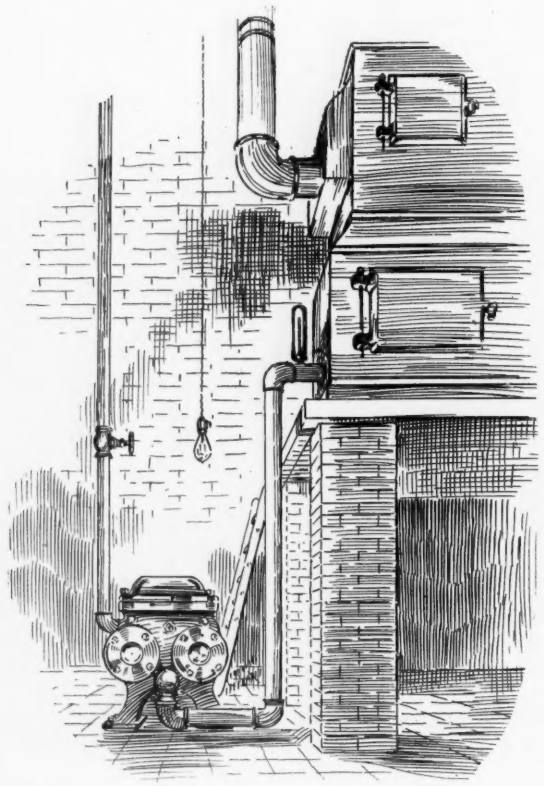
Since a record of efficiency in the existing plant is the first thing to establish, the natural way to secure



IT IS EASIER TO NEGLECT THE COMBUSTION CHAMBER THAN TO BURN YOUR FINGERS ON A DOOR LIKE THIS

it is as follows: Study first the equipment and all the peculiarities of the equipment in general and as installed in that particular place. After this has been done a careful observation of its operation should be made and a proper sequence of events in its operation decided upon. Operating tests are important, in this connection, and should be coincident with this study. The personnel of the organization should next receive careful attention and be studied with a view to correction or change. It never paid anyone to keep any man upon whose services a profit cannot be figured and yet it is invariably better to make a good man out of a poor one, than to make a change. It lends an interest to the game as well, and if a poor man is discharged, the chances are that the man employed in his place will not be better, so I contend for the education and development of the man on the job. Always remember that it takes no skill to discharge a man; that is usually a lazy man's way of building up an organization, and a slow way at that.

One of the best chief engineers of my acquaintance said to me, many years ago, that every oiler in his power house was a man who had served his time in either the German navy or the German army. A look at his power house showed why he preferred these men, but he had hired them because they were already trained in efficiency. Comparing them with the boilers in the power houses under my supervision at the time, made me ashamed of my own efforts. These men of his took pride in their work, had a regularly scheduled sequence of operations to perform and in the intervals of rest were quietly standing at "attention" in the immediate vicinity of their work. They were never found away



A CHECK ON TEMPERATURES IS AN IMPORTANT AID TO EFFICIENCY

from their responsibility, never congregated in a group discussing anything. They took their duties seriously and performed them efficiently.

Discipline

I crossed the Atlantic once on a German boat, and in all departments of that vessel I found the same efficiency everywhere. Everyone knew his work and performed it in a clock-like way. When I visited the engine room I was told to back down the connecting stairs and when I persisted in going down forward, the tour was stopped until I agreed to follow instructions. It was useless to argue that I was as much at home on those iron stairs as was the engineer. The routine performance was for passengers to walk downstairs after the fashion of a crab and I had to conform to it.

The impression left with me today is that I would feel safer on a German boat than on an English one, and I am ready to believe they show a more efficient relation between tons, miles, and hours than do less ably disciplined carriers.

Creating Interest

In building up the organization to such a point, the creation of interest among the men is of paramount importance and records of performance showing totals are not sufficient. Separate records of the showing made by each man, and supplies, delays, and repairs charged to each unit are essential. The elimination of waste in the plant will pay for all the attendant expense of such records, and all tests as well, in most cases. After these 2 elements of efficiency—the best operation of the existing plant, and the education of the men employed—have been provided for, it will be time to consider the last element—improvement and substitution of equipment.

This requires more study than anything else and any item should be considered from all the unfavorable viewpoints before any recommendations are made. The savings to be expected from better equipment are, in many cases, too much like the money made in stock market operations—"paper profits." We all know where there are cooling towers that do not pay the interest and depreciation out of the saving they effect; stoker installations that save no labor, are an additional expense in interest and up-keep, and burn coal less economically than by hand firing; superheaters, where superheat does not pay; oiling systems that waste oil and save no labor; coal and ash handling equipment that requires more value in repairs alone than is saved in labor by it; coal unloading devices that do not compare favorably with hand labor and are not as flexible and many other items of supposed saving that did not come out just as expected.

Common Sense

There are many sides to the matter of efficiency and the most important thing for the man in charge of affairs to possess is old-fashioned common sense. Our entire engineering fraternity are peculiarly apt to lack it at times, and I suppose all of us have done such things as to measure roughly the diameter of a pulley with a 6-ft. wooden rule and then multiply it by 3.141,59 to find the circumference, giving no thought to the absurdity of making a rough measurement and then carrying the multiplication out to 5 decimal places, when a multiplication by 3 1/7 would be sufficient.

In the same way we may use a Parr calorimeter to determine the value of a coal sample and, after making a temperature reading with a more or less accurate thermometer, and otherwise allowing some elements of error to creep in, calculate that the B.t.u. of the coal is 12,999, or whatever it happens to work out, and use that figure in subsequent calculations when we know, if we stop to think at all, that we are probably not within a hundred B.t.u. of correct figures anyway, and should use the nearest even hundred.

Many times someone announces a result taken from a slide rule that a moment's exercise in mental arithmetic

will disprove and, when his attention is called to it, says, "I had the decimal point in the wrong place."

The engineer who will insist on delicate water-weighing apparatus for each boiler and whose water is so bad he has to blow down the boilers several times a day and has no equally accurate means for recording that performance, is not using common sense in checking his efficiency work, any more than is the one who shows very high combined efficiency of boiler and furnace on an evaporative test, just because he has been crowding a "wet steamer" so hard, a great deal of water that was never evaporated has been carried over and he did not check the quality of the steam.

How many of us are in the habit of accepting as a fact any statement in a printed book, regardless of the authority, and even when we would not agree with the same verbal statement made by a much better authority. The same books on refrigeration that say to purge the permanent gases "from the top" of the ammonia condenser will tell you that in an ammonia accident the safest place is "as close to the floor" as possible. We are expected to believe that ammonia gas varies in its properties, depending on whether it is free or in a condenser, I presume.

An engineer will figure tons of copper conductors for an industrial plant that is gridironed with railroad tracks and when you ask him why the rails cannot be used for half of it, will say, "It is not good practice." We cannot help noticing that the surface-car lines and elevated roads keep right on doing it just the same, and are credibly informed that the largest manufacturers of electric power have everything that is made of iron or steel at their plants—piping, rails, structural steel—grounded for the same purpose.

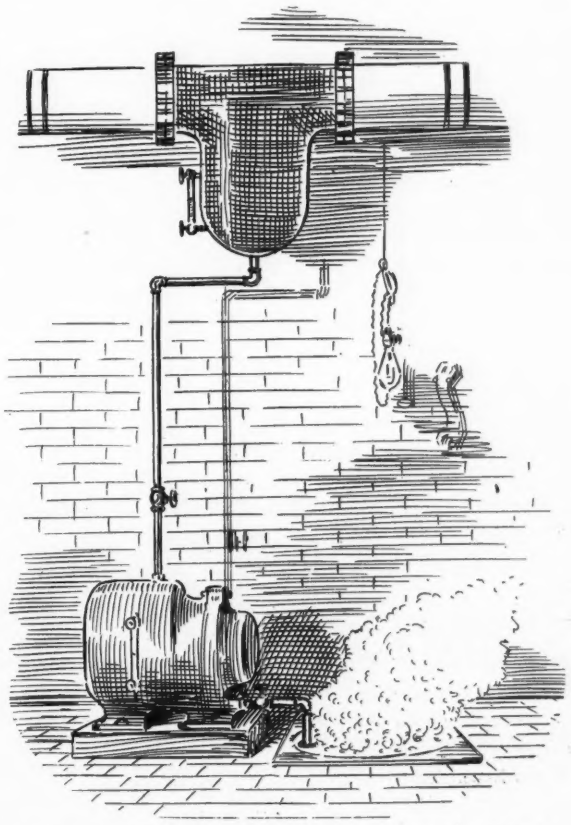
I am inclined to rebel against that term, "good practice," and have seen too many things that "could not possibly work," perform beautifully, to follow the beaten path when there is a good-looking cross cut that seems shorter.

Judgment

Reflective judgment, as distinct from practical judgment, would be the way to define the difference which can mean success or failure so often in so-called "efficiency" work. The tendency of all such work is not really to make the human units further down the scale in the organization work harder, but to require much more and harder work from the men at the top, the ones in charge of affairs. The creation of proper habits of work, the establishment of a proper sequence of events to be followed in each man's work, the correct mental attitude of the owners, analytical methods of study and broad consideration of every operating detail on the part of the chief—these are the important elements of success.

First train yourself and then teach others. It will be easier to check results and show the actual progress made if one division of a power plant at a time is attacked. Pump house, water system, boiler room, engine room, repair department, ice plant, or whatever section you attempt, will afford all the field you require at first. Any engineer will concede that it is better to make complete drawings before doing work because it is cheaper to "make all the mistakes on paper"; but it is also cheaper to make mistakes in mind than on paper, so do not fail to realize that the most important thing of all is to develop correct habits of thought.

You will never solve all the problems. We see losses every day that no one has succeeded in stopping and some of them look simple of remedy, too. Why does not someone find a way to thaw cans in an ice plant so that so much ice will not be melted? That old hot-water scheme costs 2 to 3 per cent of the ice made, but how else can it be done? I'm sure I don't know.



TRAPS BLOWING INTO THE SEWER MEAN A BIG WASTE

Above all things else, get all the ideas and suggestions you can from everyone, whether in your employ or not, and never say "Efficiency" or "Scientific Management" loud enough for anyone in the plant to hear you. It is a sad commentary on the work of "Efficiency Engineers" that so many people of common sense and judgment are of the opinion that the business is being slowly murdered in the house of its friends and that such terms as "Industrial Betterment," etc., do not cause the alarm and uneasiness that the more generally advertised terms do. In conclusion, just one word of advice: Be careful!

It is stated that the New York, New Haven & Hartford Railroad will shortly build a new power plant in New Haven, and that electric service on the road will then be extended at least as far as that city.

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Why An Efficiency Number?

Are plants, then, so inefficient that an entire big number need be devoted to the subject? Yes and no. If all plants were as efficient as the best, there would be little need for a definite campaign for efficiency. But to your mind will come at once a number of plants where results are not what they should be. And here careful distinction should be made between efficiency and economy. The former has to do with making the best use of present equipment; the latter with providing and using the facilities which will get the biggest result per dollar of expense. And, as Mr. Yeomans points out, it is always best to begin with efficiency, and after that is secured, look about to see how greater economy may be attained.

Greatest efficiency may likely mean, however, some expenditure for rearrangement, for tools and for measuring instruments, but this will be small, and the gains to be made can quickly be proved, by even a partial expenditure which will show results.

What evidence is there that it will pay? First, there is absolute necessity for the small plant to put its house in order. It is not only in the large and medium-size cities that the central station is reaching out to displace the individual plant, but great networks are forming all over the country and the supply of power to farms and factory villages is being pushed.

It is well to be fair, even if the other fellow is not, and those who believe that the central station is wrong in its expressed determination to do away with individual plants, must agree that in many places—the farm, the small loft factory, the single machine, the shop requiring power only at intervals—the central station has its legitimate field.

But Mr. Trautschold shows that the cost of producing power decreases but slowly above 1000 hp. with size of plant, and it is hardly conceivable that any individual plant of 1000 hp. or over cannot, under proper conditions of operation, meet the cost of central-station power. Even for considerably smaller plants, where industry or heating calls for steam, the balance should show on the side of the individual plant, for the cost of production expense, interest and taxes, the central-station current must add transmission expense, overhead and enough to pay dividends on the stock.

Where and how much may one expect to save by getting after efficiency? This can best be answered by a few instances from experience. In one plant where the fuel cost was 81 per cent of the cost for power, a saving of ¼ the fuel cost was made by selecting the right fuel, buying it right and burning it right; that is, by getting the best coal for the furnace, buying on specification and test, and burning under conditions which were kept right for that coal. In a refrigerating plant, scale accumulated in the ammonia condenser pipes until at the end of 8 mo. the increase in fuel needed was 1 ton a day and the loss in reduced capacity for ice was $20 a day. In the plant where the bill for lubricants was $3300 a year, a saving of $1000 was made in oil and waste; 1st, by filtering used oil; 2nd, by reclaiming the oil from waste and reusing the waste; 3rd, by recovering oil from the exhaust steam for use on rough bearings; 4th, by keeping track of oil used on each machine. Instances might be multiplied, but these show the wide field for study and improvement, and the possibilities for gain.

Power must be made efficiently in the individual plant if it is to compete with the central station. Further, the fact must be capable of proof, from indisputable records that the power is being made efficiently and economically.

It is the endeavor in this issue to indicate how both these may be done. But in making the effort it must be kept always in mind that the co-operation of the working force is essential. How to get it becomes a question of prime importance. Emerson gives the following quotation, which is worth passing on: "A man will not do what he ought to do because there is more money in it, because it is right, or for any other so-called rational reason. He will do what you ask him to do if he likes you, and he will not like you unless you first like him." It comes back to an everyday application of that homely, much-neglected Golden Rule. Give to the other fellow the cordial, kindly interest and friendship that you want from him. A cheerful greeting, willingness to explain patiently, repeatedly, just what you are after and how you expect to get it, mild reproof where it must be given, praise and credit where deserved; these are the materials of which co-operation is builded.

Special alertness must be secured,. which calls for great effort and deserves special reward. This will come partly in easier conditions of working, more convenient tools and better surroundings; but on top of this, the exertion to get the best possible results should bring extra pay. And to make it easy to keep up the interest and make the exertion, the spirit of the game must be maintained. Playing ball on a boiling-hot day in August isn't a hardship; no more need firing a boiler be if we are trying to beat another fellow's mark or even to beat a set standard. The essentials of a sport are matching skill against obstacles to get a certain result; and the obstacles must be great enough to require one's best effort. Repacking a stuffing box isn't a game. But doing it against time is a game, and a bonus of special pay, if you win, makes the prize.

Patience! That's the great need, after the cordial co-operation is secured. To find what should be done and how best to do it; to get the consent and authorization of those above in authority and keep trying and teaching and explaining until the results begin to show. One man who knows has said that it takes 6 months to make your observations, find what you want to do and get your first man trained, and another 10 months before all in the plant are working in harmonious effort for the best possible results. Some gains can be made, of course, much sooner, but to reach the best possible takes time. Patience, and go slow—but keep going.

MAKE IT A RULE not only to be prompt in all your appointments, but a little ahead of time.

IF YOU INTEND to be happy, don't be foolish enough to wait for a just cause.

BE AMBITIOUS. To rest content with results achieved is the first sign of business decay.

News Notes

AT MARSHALL, MICH., the Commonwealth Power Co. has begun the erection of a large substation.

NEW ATHENS, ILL., is to be the location for the new power plant of the Southern Traction Co. of Illinois, the construction to start soon.

AN ELECTRIC LIGHT AND POWER PLANT, to cost $30,000, is being erected in Downs, Kan. The cement block building will be 50 by 72 ft. and 14 ft. high. A 300-hp. generator will propel the generator.

AN ORDINANCE AUTHORIZING a franchise to A. F. Heeb, T. J. Mulgrew and T. J. Fitzpatrick, brings to and locates in Oelwein, Iowa, a new $75,000 electric light plant, fully equipped in every respect.

SALT LAKE CITY'S new East Side high school is to have an electric generating plant of its own, thus becoming independent for its light and power. It is expected that the plant will cost in the neighborhood of $5000 or $6000.

FAIRMONT & CLARKSBURG POWER CO., Monongah, W. Va., will construct 2 hydro-electric plants, developing respectively 10,000 and 50,000 hp.; plans include 2 concrete power dams and 2 hollow-type reinforced concrete storage dams; total cost, $280,000.

SOME MONTHS AGO the property holders of Orangeburg, S. C., voted a $60,000 bond issue to raise funds wherewith to erect a new and modern water, light and power plant. These bonds will be sold on January 6, 1914, and work will be begun on the new plant shortly afterward.

THE IDAHO POWER AND CONCENTRATING CO., Ltd., has under construction, with considerable work already completed, a large hydro-electric plant of Trestle Creek, 11 miles east of Sandpoint, Idaho, on the Northern Pacific Railway. The estimated cost of the development now under way is $128,000, and the capacity of the plant is placed at 2000 hp.

THE EASTERN RAILWAYS CO., according to a Pottsville, Pa., newspaper, has completed plans for the construction of a $350,000 power house adjoining its present large plant at Palo Alto and work will probably be started before the spring. The company recently acquired an additional plot of ground adjoining its present property at Palo Alto, which will be utilized in the construction of the new building.

THE UNITED STATES CIVIL SERVICE Commission announces an open competitive examination for topographic draftsman and copyist topographic draftsman, for both men and women, on January 7 and 8, 1914, at principal places. The salary of the position of topographic draftsman ranges usually from $1000 to $1500 per annum, and for copyist topographic draftsman from $900 to $1500 per annum.

Competitors will be examined in the following subjects, which will have the relative weights indicated:

Topographic Draftsman: Drawing (a specimen of topographic drawing will be given for reproduction in india ink), 35; lettering (tests of short words in different styles of lettering, and numbers are given), 35; mathematics (comprising arithmetic, algebra to and including problems involving quadratics, plane and solid geometry, plane trigonometry, logarithms, mensuration, and projections), 30.

Copyist Topographic Draftsman: Drawing (a specimen of topographic drawing will be given for reproduction in india ink), 50; lettering (tests of short words in different styles of lettering, and numbers are given), 50. Age limit, 18 yr. or over on the date of examination. Persons who meet the requirements and desire this examination should at once apply for application Form 1312 to the United States Civil Service Commission, Washington, D. C.

Catalog Notes

CIRCULAR P-8, on Gardner duplex power pumps—packed piston, center packed plunger, plunger and ring types, has been issued by the Gardner Governor Co., Quincy, Ill.

SPRAY ENGINEERING CO., 201 Devonshire St., Boston, Mass., has issued the following bulletins: No. 23, Sprays for Cooling Condensing Water; No. 30, Spray Nozzles for scrubbing gases, settling dust, cooling air, chemical uses, spraying insecticides; No. 52, Air Washers.

H. B. UNDERWOOD & CO., 1025 Hamilton St., Philadelphia, Pa., has just issued its 1914 calendar.

FULTON-TOSI OIL ENGINE is illustrated in a new circular giving its points of superiority. The engine is manufactured by Fulton Iron Works, St. Louis, Mo.

GOODWIN hollow safety set screws, made by the Bristol Co., Waterbury, Conn., are described and illustrated in a folder recently received.

THE ALEXANDER HAMILTON circular in the Makers of Unions series published by Jefferson Union Co., Lexington, Mass., was recently received.

LIBERTY TUBE CLEANERS for boiler scale are described and illustrated in a pamphlet just issued from Liberty Manufacturing Co., 6903 Susquehanna St., Pittsburgh, Pa.

A PAMPHLET FROM The Morrison Boiler Co., Sharon, Pa., illustrates Morrison water-tube boilers and quotes a letter relating a company's experience with them.

ROUND TYPE direct-current motors are described and illustrated in Bulletin No. 247, superseding No. 219, from Sprague Electric Works of General Electric Co., 527 West 34th St., New York.

"HOW MUCH EXCESS FUEL Does Your Boiler Require?" is a query on the front cover of a booklet on the subject of Federal boiler graphite, which is manufactured by the Federal Graphite Mills, Cleveland, O.

BULLETIN A4173, recently issued by the General Electric Co., describes the GE-201 ventilated commutating pole railway motor, and supersedes the company's previous bulletin on the subject.

These tables contain data especially worked out or carefully selected that are vital to your work. You may need them at any time and should preserve them. A handy, serviceable, loose-leaf cover in which these tables fit exactly, will be sent you for 30 cents in currency or stamps.

PRACTICAL ENGINEER

COAL-BURNING STEAM PLANTS FOR MANUFACTURING SERVICE

Land for engine and boiler rooms
Engine and boiler room building
Chimneys
Engines, etc. Comp. Condensing—Larger sizes triple
Boilers
Feed pumps, boiler
Accessories
Foundations
Piping
Installation
Freight and cartage
} Total Cost of Plant.

$$\frac{\text{Total Cost of Plant}}{\text{Horsepower capacity of Plant}} = \text{Cost of Plant per horsepower} = \text{Item B.}$$

FIXED CHARGES:—

Depreciation —5% total cost
Repairs —2%
Interest. —6%
Insurance —1%
Taxes —2%—¾ cost
} 15½% of Item B=Yearly Burden per hp.

Fuel and attendance for 24-hr. day taken at twice that for 10-hr. day; oil, supplies, etc., at 2.4 times.

Wage scale per day: Day engineer, $4; night engineer, $3; helpers and firemen, $2.

—Reginald Trautschold.

PRACTICAL ENGINEER

TOTAL COST OF POWER (YEARLY AVERAGE)—STEAM POWER HOUSE—PER BRAKE HORSEPOWER

—Coal-Burning Plant—

Size of Plant Hp.	COST OF COAL PER TON					
	$2.00 Service		$3.00 Service		$4.00 Service	
	10-hr.	24-hr.	10-hr.	24-hr.	10-hr.	24-hr.
100	$61.06	$96.42	$71.06	$116.42	$81.06	$136.42
200	52.93	73.43	61.63	101.43	70.63	119.43
300	46.93	73.86	54.60	90.36	62.85	106.86
400	41.75	67.93	49.75	83.03	57.75	99.03
500	36.52	58.93	43.62	72.76	50.72	86.96
600	31.96	51.42	38.10	63.62	44.30	76.02
700	28.42	45.04	33.92	56.44	39.42	67.44
800	25.22	39.93	30.02	49.63	34.82	59.23
900	22.72	35.93	26.87	44.12	31.02	52.42
1000	20.40	31.76	23.86	38.68	27.30	46.58
1500	18.49	28.25	21.79	33.85	24.09	39.45
2000	17.31	26.10	20.43	30.90	22.11	35.70
2500	16.33	24.35	19.43	28.35	20.53	32.75
3000	15.32	22.47	17.43	26.15	19.02	29.87
4000	14.40	20.90	16.12	24.17	17.84	27.78
5000	13.45	19.29	15.00	22.39	16.55	25.49

Size of Plant Hp.	COST OF COAL PER TON	
	$5.00 Service	
	10-hr.	24-hr.
100	$91.06	$156.42
200	79.63	137.43
300	71.10	123.36
400	65.75	115.03
500	57.82	101.16
600	50.50	88.42
700	44.92	78.44
800	39.02	68.83
900	35.17	60.72
1000	30.75	52.48
1500	26.89	45.05
2000	24.51	40.50
2500	22.63	36.95
3000	20.87	33.57
4000	19.56	31.22
5000	18.10	28.59

Cost of Power is at Engine; no transmission or conversion losses considered.

—Reginald Trautschold.

PRACTICAL ENGINEER

OIL-BURNING STEAM PLANTS FOR MANUFACTURING SERVICE

Land for engine and boiler rooms
Engine and boiler room building
Chimneys
Engines, etc. Comp. Condensing
Boilers
Feed pumps, boiler
Accessories
Oil burners
Oil storage tanks
Pre-heaters, oil pumps, regulators
Foundations
Piping
Installation
Freight and cartage
} Total Cost of Plant

$$\frac{\text{Total Cost of Plant}}{\text{Horsepower capacity of Plant}} = \text{Cost of Plant per horsepower} = \text{Item B.}$$

FIXED CHARGES:—

Depreciation —5% total cost
Repairs —2%
Interest. —6%
Insurance —1%
Taxes —2%— ¾ cost
} 15½% of Item B = Yearly Burden per hp.

Fuel and attendance for 24-hr. day taken at twice that for 10-hr. day; oil, supplies, etc., at 2.4 times. Wage cost per day: Day engineer, $4; night engineer, $3; helpers and firemen, $2.

—Reginald Trautschold.

PRACTICAL ENGINEER

TOTAL COST OF POWER (YEARLY AVERAGE)—STEAM POWER HOUSE—PER BRAKE HORSEPOWER

—Oil-Burning Plant—

Size of Plant Hp.	COST OF FUEL PER GALLON					
	2.0 cts. Service		2.5 cts. Service		3.0 cts. Service	
	10-hr.	24-hr.	10-hr.	24-hr.	10-hr.	24-hr.
100	$53.16	$79.80	$57.16	$87.80	$61.16	$95.80
200	45.85	69.13	49.45	76.33	53.05	83.53
300	39.61	59.78	42.91	66.38	46.21	72.98
400	35.63	54.25	38.83	60.65	42.03	67.05
500	31.08	47.32	33.92	53.00	36.76	58.68
600	27.13	41.30	29.61	46.26	32.09	51.22
700	23.29	35.80	25.49	40.20	27.69	44.60
800	21.48	32.45	23.40	36.29	25.32	40.13
900	19.34	28.76	20.95	31.98	22.56	35.20
1000	17.67	26.03	19.07	28.83	20.47	31.63
1500	16.11	23.18	17.23	25.43	18.36	27.68
2000	15.17	21.47	16.14	23.42	17.12	25.37
2500	14.30	20.03	15.15	21.73	16.00	23.43
3000	13.55	18.66	14.30	20.16	15.05	21.66
4000	12.76	17.38	13.46	18.78	14.16	20.18
5000	12.04	16.23	12.67	17.50	13.31	18.77

Size of Plant Hp.	COST OF FUEL PER GALLON	
	3.5 cts. Service	
	10-hr.	24-hr.
100	$65.16	$103.80
200	56.65	90.73
300	49.51	79.58
400	45.23	73.45
500	39.60	64.36
600	34.57	56.18
700	29.89	49.00
800	27.24	43.97
900	24.17	38.42
1000	21.87	34.43
1500	19.48	29.93
2000	18.09	27.32
2500	16.85	25.13
3000	15.80	23.16
4000	14.86	21.58
5000	13.94	20.04

Cost of Power is at Engine; no transmission or conversion losses considered.

—Reginald Trautschold

TOTAL COST OF POWER (AVERAGE)—STEAM POWER PLANT—PER BRAKE HORSE-POWER (HOUR)

—Coal-Burning Plant—

Size of Plant Hp.	COST OF COAL PER TON									
	$2.00 Service		$3.00 Service		$4.00 Service		$5.00 Service	
	10-hr.	24-hr.	10-hr.	24-hr.	10-hr.	24-hr.	10-hr.	24-hr.
100	$0.02000	$0.01333	$0.02355	$0.01575	$0.02628	$0.01843	$0.02954	$0.02115
200	.01708	.01128	.02000	.01371	.02290	.01618	.02583	.01859
300	.01505	.00999	.01773	.01221	.02040	.01445	.02305	.01669
400	.01354	.00908	.01615	.01127	.01875	.01340	.02133	.01554
500	.01186	.00783	.01321	.00982	.01645	.01176	.01876	.01370
600	.01036	.00694	.01238	.00860	.01440	.01029	.01640	.01196
700	.00925	.00615	.01115	.00763	.01281	.00911	.01460	.01060
800	.00822	.00546	.00983	.00671	.01132	.00801	.01297	.00932
900	.00739	.00486	.00874	.00596	.01007	.00709	.01140	.00821
1000	.00666	.00430	.00776	.00523	.00888	.00616	.01000	.00709
1500	.00601	.00383	.00693	.00458	.00784	.00533	.00875	.00609
2000	.00563	.00354	.00641	.00418	.00719	.00483	.00797	.00548
2500	.00531	.00330	.00599	.00386	.00667	.00443	.00737	.00500
3000	.00499	.00305	.00558	.00354	.00619	.00404	.00679	.00453
4000	.00468	.00283	.00524	.00329	.00580	.00376	.00636	.00422
5000	.00437	.00261	.00488	.00303	.00538	.00345	.00588	.00386

Cost of Power is at Engine; no transmission or conversion losses considered.

—Reginald Trautschold.

AVERAGE YEARLY COST PER HORSEPOWER; COAL-BURNING STEAM PLANT

A Size Hp.	B First Cost	C Burden 15½% of B	D Attendance 10-hr. day	E Attendance 24-hr. day	F Oil Waste & Supplies 10-hr. day	G Oil Waste & Supplies 24-hr. day	H Coal, Tons 10-hr. day	I Coal, Tons 24-hr. day
100	$172.00	$26.66	$12.00	$24.00	$2.40	$5.76	10.00	20.00
200	146.00	22.63	10.00	20.00	2.00	4.80	9.00	18.00
300	126.00	19.53	8.60	17.20	1.72	4.13	8.25	16.50
400	110.00	17.05	7.25	14.50	1.45	3.48	8.00	16.00
500	96.00	14.88	6.20	12.40	1.24	2.88	7.10	14.20
600	84.00	13.02	5.40	10.80	1.08	2.60	6.20	12.40
700	76.00	11.78	4.70	9.40	.94	2.26	5.50	11.00
800	68.00	10.54	4.15	8.30	.83	1.99	4.80	9.60
900	64.00	9.92	3.75	7.50	.75	1.80	4.15	8.30
1000	60.00	9.30	3.50	7.00	.70	1.68	3.45	6.90
1500	58.00	8.99	3.25	6.50	.65	1.56	2.80	5.60
2000	56.50	8.76	3.15	6.30	.60	1.44	2.40	4.80
2500	55.00	8.53	3.05	6.10	.55	1.32	2.10	4.20
3000	54.00	8.37	2.75	5.50	.50	1.20	1.85	3.70
4000	52.00	8.06	2.50	5.00	.40	.96	1.72	3.44
5000	50.00	7.75	2.25	4.50	.35	.84	1.55	3.10

—Reginald Trautschold.

TOTAL COST OF POWER (YEARLY AVERAGE)—STEAM POWER HOUSE—PER BRAKE HORSEPOWER

—Oil-Burning Plant—

Size of Plant Hp.	COST OF FUEL PER GALLON									
	4.0 cts. Service		4.5 cts. Service		5.0 cts. Service		5.5 cts. Service	
	10-hr.	24-hr.	10-hr.	24-hr.	10-hr.	24-hr.	10-hr.	24-hr.
100	$69.16	$111.80	$73.16	$119.80	$77.16	$128.80	$81.16	$135.80
200	60.25	97.93	63.85	105.13	67.45	112.33	71.05	119.53
300	52.81	86.18	56.11	92.78	59.41	99.38	62.71	105.98
400	48.43	79.85	51.63	86.25	54.83	92.65	58.03	99.05
500	42.44	70.54	45.28	75.72	48.12	81.40	50.96	87.08
600	37.05	61.14	39.53	66.10	42.01	71.02	44.49	76.02
700	32.09	53.40	34.29	57.80	36.49	62.20	38.69	66.60
800	29.16	47.81	31.08	51.65	33.00	55.49	34.92	59.33
900	25.78	41.64	27.39	44.86	29.00	48.08	30.61	51.30
1000	23.27	37.23	24.67	40.03	26.07	42.83	27.47	45.63
1500	20.61	32.18	21.73	34.43	22.86	36.68	23.98	38.93
2000	19.07	29.27	20.04	31.22	21.02	33.17	21.99	35.12
2500	17.79	26.83	18.55	28.53	19.40	30.25	20.25	31.93
3000	16.55	24.66	17.30	26.16	18.05	27.66	18.80	29.16
4000	15.56	22.98	16.26	24.38	16.96	25.78	17.66	27.18
5000	14.58	21.31	15.21	22.58	15.85	23.85	16.48	25.12

Cost of Power is at Engine; no transmission or conversion losses considered.

—Reginald Trautschold.

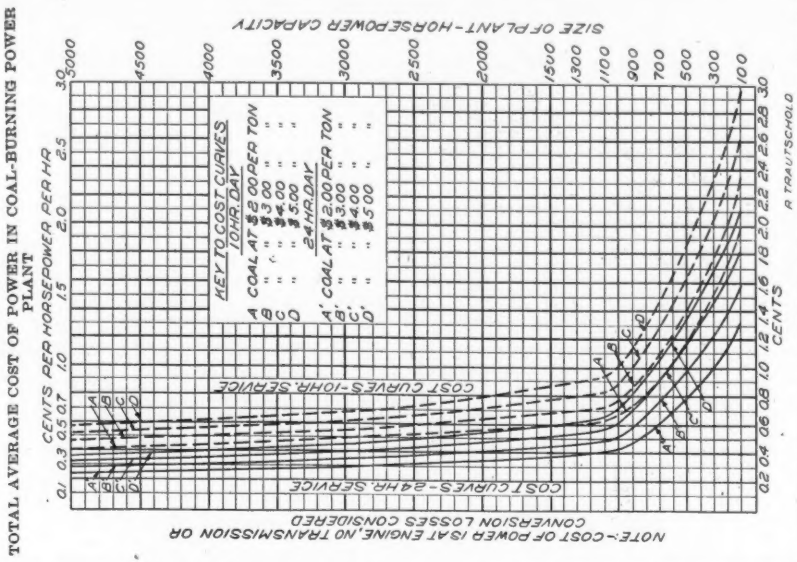
AVERAGE YEARLY COSTS PER HORSEPOWER; OIL-BURNING STEAM PLANT

A Size Hp.	B First Cost	C Burden 15½% of B	D Attendance 10-hr. day	E Attendance 24-hr. day	F Oil, Waste & Supplies 10-hr day	G Oil, Waste & Supplies 24-hr day	H Gal. Fuel 10-hr. day	I Gal. Fuel 24-hr day
100	$177.50	$27.50	$7.20	$14.40	$2.46	$5.90	800	1600
200	151.00	23.40	6.00	12.00	2.05	4.93	720	1440
300	130.00	20.15	4.50	9.00	1.76	4.23	660	1320
400	113.50	17.60	3.75	7.50	1.48	3.55	640	1280
500	99.00	15.35	3.10	6.20	1.27	3.05	568	1136
600	86.50	13.40	2.70	5.40	1.11	2.66	496	992
700	78.50	11.17	2.35	4.70	.97	2.33	440	880
800	70.00	10.85	2.10	4.20	.85	2.04	384	768
900	66.00	10.23	1.90	3.80	.77	1.85	322	644
1000	62.00	9.60	1.75	3.50	.72	1.73	280	560
1500	60.00	9.30	1.65	3.30	.66	1.58	225	450
2000	58.40	9.06	1.60	3.20	.61	1.41	195	390
2500	56.70	8.79	1.55	3.10	.56	1.34	170	340
3000	55.70	8.64	1.40	2.80	.51	1.22	150	300
4000	53.60	8.30	1.25	2.50	.41	.98	140	280
5000	51.50	7.99	1.15	2.30	.36	.86	127	254

—Reginald Trautschold.

PRACTICAL ENGINEER

TOTAL AVERAGE COST OF POWER IN COAL-BURNING POWER PLANT


SIZE OF PLANT-HORSEPOWER CAPACITY
CENTS PER HORSEPOWER PER HR.
CENTS
KEY TO COST CURVES
10 HR. DAY
A COAL AT $2.00 PER TON
C " " $3.00 " "
E " " $4.00 " "
G " " $5.00 " "
24 HR. DAY
A' COAL AT $2.00 PER TON
C' " " $3.00 " "
E' " " $4.00 " "
G' " " $5.00 " "
COST CURVES-10 HR. SERVICE
COST CURVES-24 HR. SERVICE
NOTE-COST OF POWER IS AT ENGINE, NO TRANSMISSION OR CONVERSION LOSSES CONSIDERED
R. TRAUTSCHOLD

PRACTICAL ENGINEER

PROPERTIES OF INJURIOUS IMPURITIES FOUND IN FEED-WATER

Substance in Solution	Chemical Formula	Effect on Steam Boilers	Effect on Soaps, Dyes, Tannins, etc.	Chemicals or Other Remedy Used	Method of Removal after Treatment	Substance left in Solution
Carbonate of Lime	$CaCO_3$	Soft Scale	Curdling	Lime or Heating	Sedimentation	None
Carbonate of Magnesia	$MgCO_3$	Soft Scale	Curdling	Heating	"	None
Sulphate of Lime	$CaSO_4$	Hard Scale	Curdling	Soda Ash	"	Sulphate of Soda
Sulphate of Magnesia	$MgSO_4$	Hard Scale	Curdling	Soda Ash and Lime	"	Sulphate of Soda
Chloride of Magnesia	$MgCl_2$	Corrosion	Curdling	Soda Ash and Lime	"	Chloride of Soda
Chloride of Lime	$CaCl_2$	Corrosion	Curdling	Soda Ash	"	Chloride of Soda
Sulphuric Acid	H_2SO_4	Corrosion	Decomposition	Soda Ash and Lime	"	Sulphate of Soda
Carbonic Acid Gas	CO_2	Corrosion	None	Lime	"	None
Nitrate of Magnesia	N_2Mg_3	Corrosion	Curdling	Lime and Soda Ash	"	Nitrate of Soda
Nitrate of Lime	$CaNO_3$	Corrosion	Curdling	Lime and Soda Ash	"	Nitrate of Soda
Alkali Carbonates		Priming or Foaming	None	Blowing off	"	Alkali Carbonates
Alkali Sulphates		Priming or Foaming	None	Blowing off	None	Alkali Sulphates
Mud and Suspended Matter		Caking and Foaming	Interference	Sulphate of Iron and Lime	Sedimentation	None
Organic Matter		Foaming	Interference	Sulphate of Iron and Lime	"	

PRACTICAL ENGINEER

TOTAL COST OF POWER (AVERAGE)—STEAM POWER HOUSE—PER BRAKE HORSE-POWER (HOUR)

—Oil-Burning Plant—

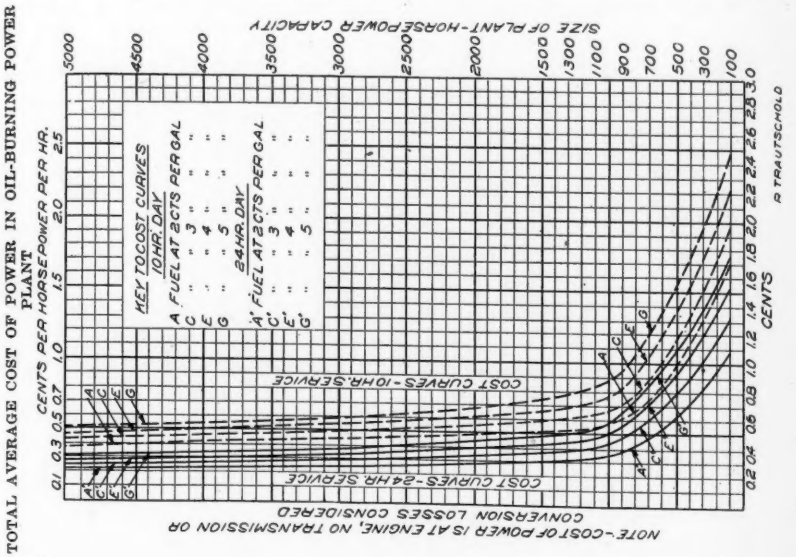
Size of Plant Hp.	COST OF FUEL PER GALLON							
	2.0 cts. Service		2.5 cts. Service		3.0 cts. Service		3.5 cts. Service	
	10-hr.	24-hr.	10-hr.	24-hr.	10-hr.	24-hr.	10-hr.	24-hr.
100	$0.01724	$0.01080	$0.01855	$0.01187	$0.01984	$0.01296	$0.02117	$0.01403
200	.01489	.00935	.01605	.01032	.01721	.01130	.01840	.01227
300	.01287	.00808	.01394	.00898	.01500	.00986	.01610	.01075
400	.01159	.00734	.01261	.00821	.01365	.00906	.01470	.00993
500	.01010	.00639	.01100	.00718	.01191	.00793	.01286	.00870
600	.00879	.00558	.00962	.00626	.01042	.00692	.01121	.00760
700	.00725	.00484	.00829	.00544	.00868	.00602	.00970	.00663
800	.00699	.00439	.00760	.00491	.00823	.00542	.00885	.00595
900	.00629	.00388	.00680	.00433	.00732	.00476	.00784	.00520
1000	.00574	.00352	.00619	.00390	.00665	.00427	.00711	.00466
1500	.00524	.00314	.00560	.00344	.00596	.00372	.00633	.00404
2000	.00493	.00290	.00524	.00317	.00556	.00343	.00587	.00370
2500	.00465	.00271	.00492	.00294	.00520	.00317	.00547	.00340
3000	.00440	.00252	.00464	.00273	.00489	.00293	.00513	.00313
4000	.00414	.00235	.00437	.00254	.00460	.00272	.00482	.00292
5000	.00391	.00220	.00411	.00237	.00433	.00254	.00453	.00271

Cost of Power is at Engine; no transmission or conversion losses considered.

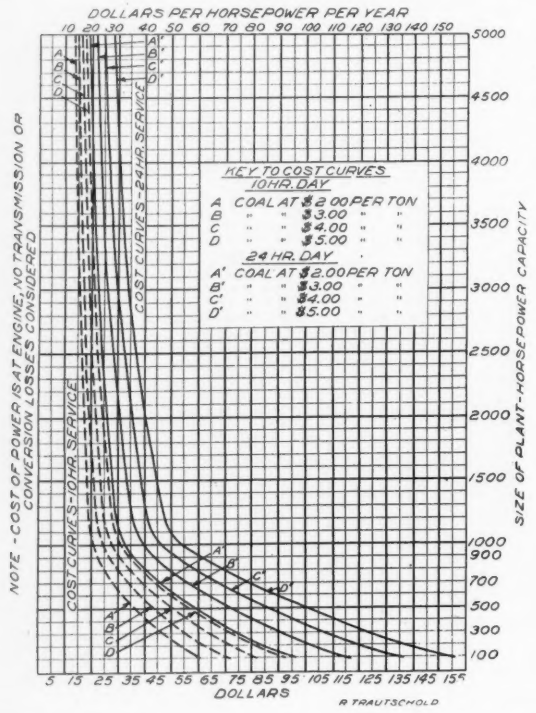
—Reginald Trautschold.

PRACTICAL ENGINEER

TOTAL AVERAGE COST OF POWER IN OIL-BURNING POWER PLANT


SIZE OF PLANT-HORSEPOWER CAPACITY
CENTS PER HORSEPOWER PER HR.
CENTS
KEY TO COST CURVES
10 HR. DAY
A FUEL AT 2 CTS PER GAL
C " " 3 " " "
E " " 4 " " "
G " " 5 " " "
24 HR. DAY
A' FUEL AT 2 CTS PER GAL
C' " " 3 " " "
E' " " 4 " " "
G' " " 5 " " "
COST CURVES-10 HR. SERVICE
COST CURVES-24 HR. SERVICE
NOTE-COST OF POWER IS AT ENGINE, NO TRANSMISSION OR CONVERSION LOSSES CONSIDERED
R. TRAUTSCHOLD

TOTAL AVERAGE COST OF POWER IN COAL-BURNING POWER PLANT


DOLLARS PER HORSEPOWER PER YEAR
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150
KEY TO COST CURVES
10 HR. DAY
A COAL AT $2.00 PER TON
B " " $3.00 " "
C " " $4.00 " "
D " " $5.00 " "
24 HR. DAY
A' COAL AT $2.00 PER TON
B' " " $3.00 " "
C' " " $4.00 " "
D' " " $5.00 " "
COST CURVES - 24 HR. SERVICE
COST CURVES - 10 HR. SERVICE
NOTE - COST OF POWER IS AT ENGINE; NO TRANSMISSION OR CONVERSION LOSSES CONSIDERED
SIZE OF PLANT - HORSEPOWER CAPACITY
5000
4500
4000
3500
3000
2500
2000
1500
1000
900
700
500
300
100
5 15 25 35 45 55 65 75 85 95 105 115 125 135 145 155
DOLLARS
R. TRAUTSCHOLD

TOTAL COST OF POWER (AVERAGE)—STEAM POWER HOUSE—PER BRAKE HORSEPOWER (HOUR)

—Oil-Burning Plant—

COST OF FUEL PER GALLON

Size of Plant Hp.	4.0 cts. Service		4.5 cts. Service		5.0 cts. Service		5.5 cts. Service	
	10-hr.	24-hr.	10-hr.	24-hr.	10-hr.	24-hr.	10-hr.	24-hr.
100	$0.02243	$0.01511	$0.02372	$0.01620	$0.02501	$0.01741	$0.02634	$0.01867
200	.01956	.01323	.02072	.01422	.02187	.01519	.02304	.01618
300	.01682	.01165	.01870	.01256	.01929	.01343	.02033	.01431
400	.01572	.01080	.01675	.01166	.01780	.01252	.01884	.01338
500	.01379	.00954	.01470	.01024	.01561	.01108	.01651	.01175
600	.01201	.00827	.01281	.00894	.01364	.00961	.01442	.01028
700	.01043	.00722	.01114	.00782	.01186	.00842	.01257	.00902
800	.00946	.00647	.01009	.00699	.01071	.00751	.01132	.00803
900	.00837	.00562	.00889	.00606	.00942	.00650	.00994	.00694
1000	.00755	.00503	.00801	.00542	.00845	.00579	.00893	.00617
1500	.00670	.00437	.00705	.00466	.00742	.00496	.00778	.00526
2000	.00619	.00396	.00650	.00422	.00683	.00448	.00714	.00475
2500	.00575	.00363	.00602	.00386	.00629	.00409	.00658	.00432
3000	.00538	.00334	.00562	.00354	.00586	.00374	.00611	.00394
4000	.00505	.00311	.00528	.00329	.00550	.00349	.00573	.00368
5000	.00473	.00288	.00494	.00305	.00514	.00323	.00535	.00339

Cost of Power is at Engine; no transmission or conversion losses considered.

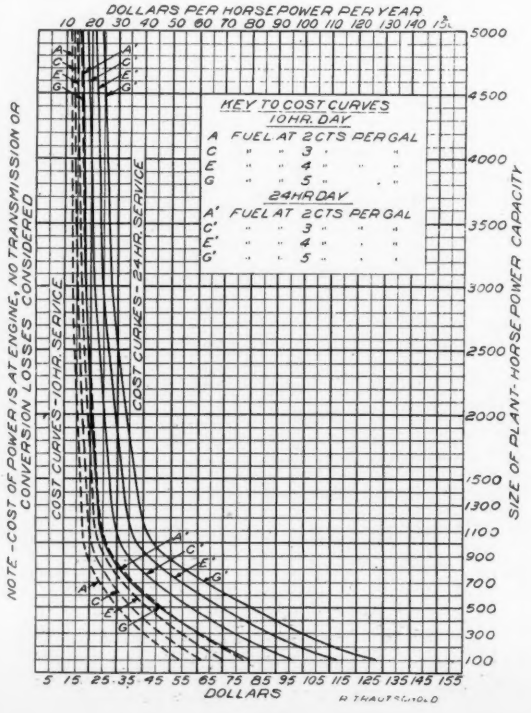
—Reginald Trautschold.

ANALYSES OF VARIOUS AMERICAN WATERS
(Impurities in Grains per U. S. Gallon)

Location	Carbonates	Sulphates and other Solids	Total Solids
Albany, N. Y. (Wells)	.....	.....	48.69
Austin, Texas	9.80	13.68	23.48
Baltimore, Md. (City Supply)	2.77	4.53	7.30
Bay City, Mich. (Bay)	8.47	40.73	49.20
Bay City, Mich. (River)	4.84	173.37	179.20
Boston, Mass. (Wells)	.....	.....	44.46
Buffalo, N. Y. (Lake Erie)	5.66	4.08	9.74
Buffalo, N. Y. (River)	6.74	6.78	13.52
Buffalo, N. Y. (Wells)	33.70	134.12	167.83
Chicago, Ill. (Wells)	32.16	55.92	88.08
Cincinnati, Ohio (River)	3.88	3.85	6.73
Clarksville, Tenn.	12.48	11.77	24.25
Dallas, Texas	19.82	53.48	73.30
Decatur, Ill.	34.48	4.27	38.75
Dunnellon, Fla.	8.39	9.51	17.90
Ensley, Ala. (Village Creek)	9.43	8.42	17.83
Hudson River (Poughkeepsie)	3.19	9.51	12.70
Indianapolis, Ind. (Creek)	2.17	0.33	2.50
Indianapolis, Ind. (Well)	1.57	36.85	38.42
Joplin, Mo.	9.09	7.71	16.80
Junction City, Kan.	20.82	9.43	30.25
Lorain, Ohio (Black River)	4.86	9.86	14.72
Lynn, Mass. (Saugus River)	1.81	4.81	6.62
Milwaukee, Wis. (Lake Michigan)	4.50	3.67	8.17
Milwaukee, Wis. (Wisconsin River)	6.23	33.07	39.30
Mississippi River (Above Missouri River)	8.24	7.77	15.01
Mississippi River (Below Missouri River)	9.64	19.90	29.54
Missouri River (Above mouth)	10.07	25.42	35.49
Missouri River (At Nebraska City)	17.85	39.84	47.69
New York, N. Y. (City supply)	2.36	1.36	3.72
New York, N. Y. (Wells)	.....	.....	58.07
Omaha, Nebr. (Wells)	14.43	59.22	73.65
Pittsburgh, Pa. (Allegheny River)	1.56	10.51	12.07
Pittsburgh, Pa. Monongahela River)	1.08	9.72	10.80
Pittsburgh, Pa. (Wells)	23.70	18.98	42.68
Sioux City, Ia.	15.31	42.41	57.72
Springfield, Mass. (Mill River)	2.68	5.54	8.14
Sumter, S. C.	0.87	8.33	9.20
Warners, N. Y. (Canal water)	2.28	12.56	20.84
Warners, N. Y. (Creek water)	13.76	35.90	49.68
Washington, D. C. (City supply)	2.87	5.73	8.60

W. B. Scaife & Sons Co.

TOTAL AVERAGE COST OF POWER IN OIL-BURNING POWER PLANT


DOLLARS PER HORSEPOWER PER YEAR
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150
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COST CURVES - 24 HR. SERVICE
COST CURVES - 10 HR. SERVICE
NOTE - COST OF POWER IS AT ENGINE; NO TRANSMISSION OR CONVERSION LOSSES CONSIDERED
SIZE OF PLANT - HORSEPOWER CAPACITY
5000
4500
4000
3500
3000
2500
2000
1500
1300
1100
900
700
500
300
100
5 15 25 35 45 55 65 75 85 95 105 115 125 135 145 155
DOLLARS
R. TRAUTSCHOLD

Bulletin A4167 is devoted to the subject of electricity in iron foundries. The bulletin is profusely illustrated with some typical applications of G-E motors in iron foundries, and contains a chapter on foundry lighting. For those looking for information on this subject, the bulletin should be of great interest.

STORY OF THE IMPERIAL is the title of a 9 by 12-in. booklet just issued by the Ingersoll-Rand Co., 11 Broadway, New York City. Novel and attractive in design, it features, in brief and simplified form, the points of design and construction maintained in the Imperial line of air compressors. It carries the reader through the various stages of construction, giving a concise and elaborate idea as to just how the machines are built.

ISSUE NO. 17 of Small Motors, a magazine published monthly by the Industrial & Power Department of the Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa., is devoted to the exceedingly popular subject of electric vehicles. Vehicle equipments are described thoroughly, the different points of construction being brought out in some detail. Characteristic curves of vehicle motors are given, as well as halftone views and cross sections of the different motors. In addition to this a number of views of pleasure and commercial vehicles are shown, and a 2-page spread of the advertisements which have appeared in technical and popular magazines on the subject of electric vehicles is given. This book may be had upon application to the company.

GENERAL ELECTRIC CO. has just issued Bulletin No. A4178, describing its 3-phase induction motor panels. These panels are for controlling induction motors of voltages of from 110 to 2200, and for operation on 25 to 60-cycle circuits. The panels described are single panels only, and not intended to be assembled as part of a switchboard. The bulletin contains a long list of standard panels, among which can be found panels suited to practically all conditions of service of this kind.

Bulletin A4176 describes the company's high voltage oil break switch, known as Type F, Form K-15. This switch may be operated by any one of several methods which are described in the bulletin, which supersedes the company's previous bulletin on this subject.

MOTOR-DRIVEN Exhaust Fan Outfits is the subject of Bulletin No. A4174, published by the General Electric Co. The bulletin is devoted to the subject of fans for ventilating purposes, and contains, in addition to other data, illustrations and dimension diagrams of the various motors built by the company for this purpose. Bulletin A4171 is devoted to a description of the company's ventilated railway motors, and supersedes the previous bulletin on that subject.

"STORAGE, DISTRIBUTION and Reclamation of Oils and other Liquids," is the title head on a handsome and convenient binder which has recently been received from S. F. Bowser & Co., of Fort Wayne, Ind. Inside the cover are bulletins, divided into 8 distinct divisions, the first, No. 2000, covering gasoline outfits of every description; the second, No. 2100 and up,, covering paint oil equipments; the third, No. 2200 and up, covering factory systems; 2300 and up, covering accessories to all lines; 2400 and up, covering store systems; 2500 and up, covering dry cleaners systems and accessories; 2600 and up, covering tanks; 2700 and up, covering power pumps; 2800 and up, covering oil filtering and and circulating systems and accessories.

In each division is found a number of descriptions showing the arrangement and use of the different kinds of apparatus. The whole forms a most complete and valuable treatise on the subjects stated in the title, and will be found a valuable reference in every engineer's library.

Trade Notes

ON PAGE 1026 of the October 15 issue was shown a number of coils wound from copper tube, and the statement was made that the process for these was patented by W. F. Smith, of Baltimore, Md. This was an error, as patents have not yet been granted to Mr. Smith, although the patents are pending. The process and design for making these coils were devised by Mr. Smith, and the coils made on machines of his design.

NELSON VALVE CO., of Chestnut Hill, Philadelphia, announces that it has recently taken over the manufacture and sale of the Erwood swing gate valve, formerly made by Walch & Wyeth, of Chicago. This valve is suited as a back pressure, atmospheric valve, atmospheric relief, safety gate, nonreturn, or combined check and gate. It will be known in the future as the Nelson-Erwood gate valve.

BECAUSE OF OUTGROWING its present plant, the Olmstead Flint Co. is removing its factory and headquarters from New York City to Lawrence, Mass. The new plant will be in operation by January 1, and branch offices will be established in New York, Boston and Philadelphia. The officers remain as before: Willard I. Olmstead, president; Stanley B. Flint, vice-president; George S. Baker, secretary; Frank M. Schiffmacher, as engineer and factory manager.

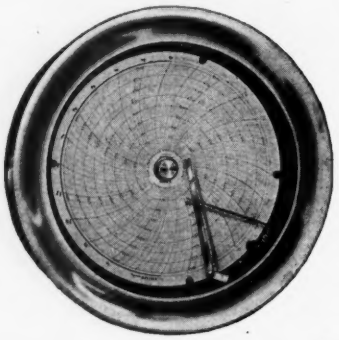
ALBERGER GAS ENGINE CO., of Buffalo, N. Y., reports the following sales of engines, 50-hp. and larger:

Hardie Bros. Co., Pittsburgh, Pa., 150-hp.; Kushequa Brick Co., Kushequa, Pa., 150-hp.; City of Bradford Gas & Power Corp., Bradford, Pa., 3 60-hp engines, each direct connected to gas compressors; Apollo Water Works Co., Pittsburgh, Pa., 80-hp.; F. C. Arner, Buffalo, N. Y., 125-hp.; 74th Regiment Armory, Buffalo, N. Y., 160-hp.; Spencer Kellogg & Sons Co., Inc., Buffalo, N. Y., 50-hp.; Albert Zurbrick, Clarence Center, N. Y., 50-hp.; Leon Henry, Hoboken, N. J., 125-hp.; Garrett Co. Coal & Mining Co., Bethlehem, Pa., 60-hp.; Bovaird & Co., Bradford, Pa., 65-hp.

DUNCAN ELECTRIC WORKS, represented by the president, Thomas Duncan, has purchased that part of the Sterling Electric Co. property, on Third St., Lafayette, Ind., which composes about ⅓ of the defunct company's holdings. The building on this property is a 3-story brick structure, and has a floor space of 20,000 sq. ft. It will be equipped with all the modern machin-

ery and mechanical devices with which the new 4-story addition, built this fall, is equipped. The manufacture of transformers will be expanded, and President Duncan states that several new articles, such as the electric fan and recording instruments, will be added to the list of products of the Duncan company.

THE UEHLING VACUUM RECORDER IN common with all Uehling records is based on the hydrostatic principle. The pen is actuated by a float resting on mercury contained in a cylindrical chamber (float chamber) secured to the lower side of a clock case. Connected with this chamber is a steel tube of the proper length to contain a column of mercury to balance the atmospheric pressure. The cross-sectional areas of the float



chamber and pressure tube are such that the pen moves over the full width of the available chart for the range of vacuum to be recorded. The instrument is made for 3 ranges, from 0-30, 20-30 and 25-30 in., giving an open scale where the readings are of importance. These instruments are made by the Uehling Instrument Co., of Passaic, N. J.

DIRECTORS OF THE North Butte Mining Co., in a meeting at Duluth, recently voted to award to the Westinghouse Electric & Manufacturing Company the contract for what will be the largest electric hoist in the 2 American Continents, and one of the largest of its kind in the world. The hoisting drums, which will be 12 ft. in diameter, will be driven by a direct-connected electric motor running at a speed of 71 r.p.m. Power will be supplied to this motor from a motor generator set equipped with a 50-ton flywheel to secure elmination of the peaks that would be drawn from the power line during period of starting and acceleration. Hoisting with this equipment will be done in balance, but the equipment is large enough to take care of unbalanced hoistings. Skips will be used for handling the ore and each skip will have a capacity of 7 tons of ore. The system of control and power equalization used will be that commonly known as the Ilgner System, in which a flywheel driven by the motor generator set is permitted to give up some of its stored energy to supply the peak load drawn by the hoisting motor. A number of special safety devices are included in the equipment, including electrically released brakes; automatic slowdown devices to prevent skip or cage ever going through head sheaves and a special controller to limit the speed when hoisting men.

PRACTICAL ENGINEER
Trade-mark reg. U. S. Pat. Office.
SEMI-MONTHLY
PUBLISHED ON THE FIRST AND FIFTEENTH OF EACH MONTH

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In Canada, subscription price $1.75 a year.
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Address all letters and make all checks and money orders payable to Technical Publishing Co., 537 S. Dearborn St., Chicago, Ill.

Any advertiser is invited to examine our paid subscription lists and Post Office mailing receipts at any time.

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Half page, one year, each insertion, $35.00.
Quarter page, one year, each insertion, $20.00.
Eighth page, one year, each insertion, $12.00.
Front cover, $150.00 per issue.

Other specified positions, regular rate plus 10 to 50 per cent.

Stippled plates used but no heavy black and white plates.

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Per line, 30 cents each insertion.

Advertisements in this section are inserted under regular headings.

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About nine words make a line. Minimum space sold, two lines.

Under classification "Position Wanted," advertisements not exceeding four lines will be inserted once for subscribers free of charge.

All copy should be received at Chicago office 18 days before date of publication.

Circulation of this issue, 24,000.

Technical Publishing Co.
537 S. Dearborn Street
Chicago

Positions Wanted

WANTED—Position as chief engineer in small plant or assistant in large plant. Have Minnesota license and can do wiring. Either steam or oil engines preferred. Otto Donath, Lakefield, Minn. 1-1-1

Wanted

IF YOU RECOGNIZE the value of approved specialties in an engine and boiler room as a means of higher efficiency; if you believe in this sort of thing to the extent that you think you could sell a well-known boiler specialty in your territory for an old established manufacturer in the power plant field, write and tell us all about yourself. On receipt of your letter we will outline our proposition in full. Address Box 324, Practical Engineer. tf.

WANTED—September 1st issue of Practical Engineer. If you have a copy of September 1st, 1913, in good condition, that you can spare, send it to us before January 1st, 1914, and we will extend your subscription two months. Address Circulation Department, Practical Engineer, 537 S. Dearborn St., Chicago.

WANTED—EVERY ENGINEER to have our pamphlet for setting valves on Corliss Engines, single and compound, with one or two eccentrics. Sent free. Lindstrom's Machine Works, 200 South Third St., Allentown, Pa. tf.

WANTED—Second-hand 14x30 Corliss engine, 10-ft. band wheel, outside bearings. Must be in first-class condition. Give full dimensions and price. James E. Nelson, care Udell Works, Indianapolis, Ind. 1-1-2

WANTED—Every local Engineers' Association to have an assortment of valuable power-plant books—Secretary write at once, for full particulars. Address Dept. C., Practical Engineer, Chicago.

IF YOU ARE a night engineer, spend a few hours each day taking subscriptions for Practical Engineer. You will be paid well. Write Subscription Dept. They will start you in at once.

WANTED—ALL STEAM USERS to have clean boilers without using compounds or chemicals in any form. Write "Otis," No. 317 Norfolk Ave., Buffalo, N. Y. tf.

WANTED—Secretary of local Engineers' Association to write us at once in regard to a very interesting proposition. Address Practical Engineer, Circulation Department.

Help Wanted

HELP WANTED—I wish to get in touch with several executives now earning from $2,500 to $10,000 yearly, who would consider offers of new connections if they came from the right concerns—executive, technical or administrative positions. I act as personal attorney (for big men only); can serve but a few at a time; I personally promulgate difficult negotiations and systematic searches for big openings; confidentially, diplomatically; bringing to bear the judgment and experience of years of success. The difficult and unusual case is particularly invited. On receipt of your address will make detailed explanation of my methods without obligating you. R. W. Bixby, Lock Box 134-49, Buffalo, N. Y. 1-1-1

WANTED—An additional subscription solicitor wanted to cover towns in the state of Indiana. Excellent chance to earn extra money. Write to Subscription Department. tf.

For Sale

CORLISS ENGINES—20x42 Hughes & Phillips Corliss engine; wheel, 12 ft. by 28 in.; in perfect condition; $800 f.o.b. cars New York. 16x36 Hughes & Phillips Corliss engine; wheel, 12 ft. by 19 in.; in perfect condition; $575. Duzets & Son, 50 Church St., New York. Send for complete "Bargain List." 1-1-2

PATENT FOR SALE—Owing to the death of its Vice-President and General Manager, this company desires to dispose of its patent on Copper-Asbestos Gaskets, known as "National Safety." For further information address Dyna Como Co., Inc., care Gladdings, Providence, R. I. 1-1-1

DIRECT-CONNECTED UNIT FOR SALE—100-kw., 440 or 220-volt, direct-current, Western Electric Generator, direct connected to Shepherd Vertical enclosed automatic engine, in use about 1½ years on temporary work, like new. Cheap before removal. H. P. Brearley, 90 West St., New York, N. Y. 12-15-2

WE HAVE FOR SALE one 125-hp. boiler and engine complete; also 75-light generator. For full description and prices, address Northern Milling Co., Wausau, Wis. 12-15-2

COOPER HEWITT LAMPS for sale, by Northwestern Marble and Tile Company, Minneapolis, Minn., four Cooper Hewitt Lamps, type "H H" 110 D.C., in first-class condition. Disposing on account of change in current. 1-1-1

OUR MODERN BLUE PRINT CHART method of electrical wiring. Write for information. Electrical Wiring Diagram Co., Box F173, Altoona, Pa. 11-15-12

Patents and Patent Attorneys

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Sparks On The Advertising Pages

New Year's, the first day of the year, has really come to mean less to us, as the holiday that ushers in the new year, than as the time when it is an almost universal custom to "turn over a new leaf" on habit, method, or policy.

Today, young men are resolving to abstain from smoking and other costly habits, families are deciding to forego certain household extravagances, and business firms are formulating (or have previously formulated to begin on this day) plans for enlargements, curtailments, methods, systems, equipment, etc., for use in their stores, offices and plants.

To an outsider—a man not understanding the American nation—there might be a certain humorous aspect in the spectacle of a people so dependent upon sentiment. A closer study, however, would reveal that this practical utilization of New Year's day is in strict harmony with the American spirit of system and efficiency. New Year's day is our annual, national tonic against *carelessness, procrastination* and *stagnation.*

* * * *

There is no disputing that the efficiency of an engineer is based on his ability to furnish ample power, heat or light at the *lowest possible* operating costs. And, these operating costs are cardinally dependent upon the efficiency of the plant equipment.

Power plant practice is always moving forward. Ideas are obsoleted, operation is changed, new principles are discovered from day to day. It is certain that a plant with antiquated principles and equipment behind its operation cannot run on the low operating cost of the modernized plant, no matter how thorough and conscientious its engineer may be. The benefit of years of science and progress is bestowed on machines, engines, and appliances of modern manufacture.

The manufacturers spend several thousands of dollars on space, illustrations and salaries of advertising men, for advertisements printed in each issue of Practical Engineer. These advertisements are concise treatises on the principles, construction and proven accomplishments of products manufactured for use in developing and carrying power.

Every engineer owes it to his plant to guard it against fossilization; he owes it to his employer to prevent the boiler and engine rooms from becoming drains of profits; he owes it to himself to avoid "getting into a rut." *And, all of these standards are gauged from the point of present day operation.*

The installation of a small improvement here—a different method there—not only often cuts operating costs to the bone, but it freshens up the spirit of workmen in the plant. The problem is to find the machine or method which exactly fits in with the requirements; and which will develop economies to exceed its cost. This knowledge can come only with a steady growth of knowledge about modern practice.

* * * *

Therefore, along with the turkey and dressing, and, perhaps the semi-humorous "check-valve" resolutions of New Year's day, it is well to include the serious resolve to keep in closer touch with all progress in the manufacture of products pertaining to the power plant profession.

The advertising section of Practical Engineer is at your service.